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The Chemistry of Creation

THE

CHEMISTRY OF CREATION:

Being a Sketch

Of the Chief Chemical and Physical Phenomena

OF

EARTH, AIR, AND OCEAN.

By ROBERT ELLIS, F.L.S.,
M.R.C.S., ETC.

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PREFACE.

THE description and explanation of the Chemical Phenomena of our Earth would require not one volume only, but many volumes. Notwithstanding the exercise of much labour and thought during the progress of this volume through the press, in the endeavour to bring it below its present limits, the importance and variety of the subjects on which it treats have precluded the possibility of curtailment. When the students of nature investigate the connexions and natural dependencies of those kingdoms which together constitute the system of creation, and even when they regard these connexions in one aspect and direction only, as in the present case, they find the subject to be exhaustless. In numerous instances, too, we should have to confess our ignorance of the actual economy of nature, and to hazard many conjectures; for the Chemistry of some of the very commonest natural processes is as yet but imperfectly understood. We have still much to learn as to the formation and fall of rain, the nutrition of plants and animals, the production of minerals, and many other important matters.

In the present work an attempt has been made to introduce most of those valuable and interesting discoveries recently made in chemical science which are related to Nature's Chemistry; and to apply them to the explanation of the chemical phenomena presented in the earth, the air and the ocean. Although this attempt has been made in familiar language, and the technicalities of science have been avoided as much as possible in describing and explaining the facts of chemical philosophy, great attention has been paid to scientific accuracy.

This volume will answer the end of its publication if, as a companion of the lover of nature, it assist him to trace in the varied phenomena of creation, the plan and action of Him who is perfect in knowledge and excellent in working.

Into the present edition of the "Chemistry of Creation," the publication of which first took place in 1850, very numerous additions and corrections have been introduced. These changes have been effected without disturbing the original plan of the book; but, in order to avoid perplexing the reader, no attempt has been made to distinguish the new matter from the old.

ALBERT J. BERNAYS.

February, 1880.

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THE ALCHEMIST.

THE CHEMISTRY OF CREATION.

INTRODUCTION.

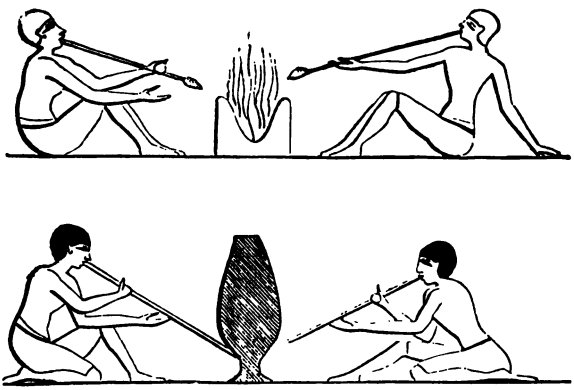
We must look through a long vista of ages if we would discover, buried in the obscurity of time, the origin of what is now called the science of Chemistry. We know little about the period when the few facts which formed its first beginning were gathered together, but it appears probable that Egypt was the country where this took place. At least, it is nearly

certain that Chemistry meant originally Egyptian or secret knowledge, as it was afterwards called the secret or the black art. Plutarch states that the old name for Egypt was Chemia, and that the name was given to it on account of the blackness of the soil.

The science of Alchemy had its origin in Egypt, and its object was the production by artificial means of the noble metals. In the fourth century we meet with the word Chemia as the name of the art of making gold and silver.

The Arabians, who, in the year 640 overran Egypt, there learnt their chemistry, and they prefixed the Arabic article *al* to *chemia*, and thus made Alchemy a familiar term for the transmutation of the base into the noble metals. A celebrated physician, of the name of Geber, paid great attention to Alchemy, and discovered some most important substances. The language used by him was often very high-flown, and, indeed, intended to disguise the processes employed from the unlearned : the name gibberish has probably its origin from Geber. Many chemical operations are described by Geber, such as distillation, filtration, sublimation, and crystallization; and by these he prepared new substances.

The accompanying hieroglyphics assure us of the fact that the Egyptians knew how to blow glass in the same manner as we do; and that thus have been formed useful chemical vessels for the early professors of this art. So far had the glass-workers of Egypt advanced in their art, that even coffins were sometimes made of glass.



GLASS-BLOWING IN EGYPT.

From the Arabians the knowledge of alchemy spread over Western Europe, and in the thirteenth century we find alchemists of the Arabian school in all the chief countries. Whilst Albertus Magnus flourished in Germany, Roger Bacon was well known in England. He was tried at Oxford for sorcery, and, to refute the charge, wrote the famous treatise in which he shows that appearances then attributed to supernatural agencies were due to common and natural causes. All the alchemists agreed that the transmutation of metals was possible with the aid of the philosopher's stone. One of them tells us:—"I had long doubted whether gold could be made from quicksilver. One who wished to convince me of my error sent me a drachm of a certain powder, of a red colour, having a peculiar odour, with which I was to make the experiment. To avoid the possibility of

fraud, I purchased the requisite vessels and materials from an ordinary warehouse. I put the mercury into the vessel, and cast the powder into it. A strong heat was then applied, and immediately the whole mass was transmuted into ten drachms of the finest gold!" We are even told in history that a celebrated philosopher, in the presence of King Edward VI., by means of a certain powder converted a mass of iron into gold, which was afterwards coined into rose nobles. The powder of the true philosopher's stone was so powerful, it was said, that a few grains of it would turn twenty tons of lead into gold. If only the Chancellor of the Exchequer possessed some of it!

We need scarcely say that the philosopher's stone was never discovered, and the art of making gold usually ended in reducing its professor to rags. Its vanity and certain results are well told in the following lines of Spenser:—

> "To lose good days, that might be better spent;
> To waste long nights in pensive discontent;
> To speed to-day, to be put back to-morrow;
> To feed on hope, to pine with fear and sorrow;
> To fret their souls with crosses and with cares;
> To eat their hearts, with comfortless despairs;
> Unhappy wights! born to disastrous end,
> That do their lives in tedious tendance spend."

It was a striking example of that unquenchable hope which will hope against hope, that the idea of an elixir conferring immortality could ever have long occupied the attention of philosophers. The origin of this remarkable error admits of being traced, like

that of so many others. "And now, lest he put forth his hand, and take also of the tree of life and live for ever," may have induced men to believe that something eaten or drunk would confer immortality. Certainly this hope continues to this day, as may be witnessed in the popularity of many patent medicines which answer to the elixir of the alchemist.

The last of the three delusions was the alcahest, or universal solvent. It may be considered also the most harmless. Properly speaking, it was simply a foolish phantasy of Chemistry. The idea was that some fluid might be produced which would instantly dissolve all substances exposed to its influence; and it seems to have had a long existence as a fanciful speculation, rather than as a subject of arduous experiment and tedious research.

In the sixteenth century Paracelsus effected the union between Chemistry and Medicine, and this continued up to the end of the seventeenth. The Aristotelian doctrine of air, earth, fire, and water held its ground until the seventeenth century, when it was disputed by Van Helmont. He denied that fire had any material existence, or that earth can be considered as an element; but even he admitted the elementary nature of air and water. It was he who made the important discovery that if a metal be dissolved in an acid, it is not destroyed, as was the general belief, but can again be obtained as a metal. It was about the middle of the seventeenth century that philosophers laid the foundation of modern Chemistry. The principles laid down in the celebrated work called *Novum Organum*, of the illustrious

Chancellor Bacon, proved most beneficial to the development of true knowledge; and as chemical philosophy was among the earliest to benefit by these principles, so it soonest began to expand and gather strength. The origin and further progress of the science has been happily compared to Milton's fine description of the erection of Pandemonium :—

> . . . . . "Soon had his crew
> Opened into the hill a spacious wound
> And digged out ribs of gold. . . . . .
> Anon out of the earth, a fabric huge
> Rose like an exhalation. . . . .
> Built like a temple."

The progress of knowledge received a powerful impulse in the foundation of the Royal Society in 1662, and of the Academy of Sciences at Paris in 1666.

Robert Boyle was the first to make the distinction between elements and compound bodies. He maintained that all bodies are to be considered as elements which are themselves incapable of further separation, but which can be obtained from a compound body, and out of which the compound can be again made up. He upheld the view that the simple advance of knowledge was the highest aim of all research. "My kingdom is not of this world. I trust that I have got hold of my pitcher by the right handle, the true method of treating this study. For the pseudo (or false) chemist seeks gold; but the true philosopher, science, which is more precious than any gold." It was in the same spirit that a just reproof was given by D'Alembert to an ambitious young man; and, as it deserves remembering, we venture to record

it. "Science," said he, "must be loved for its own sake, and not for any advantage to be derived from it. No other principle will enable a man to make progress in the sciences."

It would be impossible, in such an introduction, to do justice to the labours of Stahl, or to do more than allude to the phlogistic theory or to phlogiston, the combustible principle. Bodies like quicklime, unaltered by fire, were considered to have already undergone combustion; if phlogiston were added, the metal would result. When metals are calcined, an earthy residue or calx remains; metals are therefore compounds containing a principle (phlogiston) which causes their combustion. Sulphur and phosphorus are compounds containing a principle which causes their combustion. Stahl did not take account of the fact, proved by Boyle, that metals increase in weight when they are burnt. Nevertheless, Stahl prepared the way of the modern Chemistry.

It was on August 1st, 1774, that Joseph Priestley discovered oxygen, during his stay at Lansdowne House, Berkeley Square. He obtained it in heating red precipitate by the aid of the sun's rays concentrated with a burning-glass; and he called it dephlogisticated air, because so free from phlogiston. In 1781, Cavendish proved the composition of water, and showed that dry air was composed of 20.8 measures of dephlogisticated and 79.2 measures of phlogisticated air.

In the same year of the discovery of oxygen, Scheele discovered chlorine, which he called dephlogisticated muriatic acid.

Interesting it would be, but altogether out of place, to follow in consecutive order the further progress of the science; and we shall, therefore, hasten to its close. Lavoisier soon put an end to the phlogistic theory. Dalton gave us the atomic theory, proving that the atoms of the different elements are not of the same weight, and that the relative atomic weights of the elements are the proportions by weight in which the elements combine. Gay-Lussac discovered the law which regulates the combination of gases by volume. Sir Humphry Davy proved the compound nature of the alkalies. Berzelius proved that organic bodies obeyed the same laws as inorganic, and Wöhler showed the artificial preparation of a substance supposed to be peculiar to animal life. In the hands of the illustrious Liebig yet further progress was made, and this progress still continues.

In considering the present aspect and relations of chemistry, we are struck with the extent of its influence, and with the importance of the position it occupies. Advancing years are continually extending the one and augmenting the other. Every branch of the arts now experiences its salutary reign. While it has contributed much to the growth of other sciences, by no means directly or in the abstract related to it, it has also added a variety of substances to our present list of domestic comforts and conveniences. While it has tinged the purple and bleached the fine linen of the great, it has endowed with equal snowiness, and an equally durable though more homely lustre, the calico and coarsest fabric of the poor.

Nor has it been less valuable in adding to our remedies for the sick. For medicine, in fact, it will in future time do more, and this by reason of its intimate connection with that art, than for any other department of science. In many instances, chemistry detects the disease and points with much significance to the appropriate remedy. It analyzes the processes constantly in operation in the mysterious laboratory of the human frame, and indicates with precision many of the changes which matter undergoes in the performance of the essential functions of life. It teaches us the most appropriate food for the strong and vigorous, and directs us how to modify and rearrange the diet of the sick and feeble. Chemistry too bears more directly than will be readily conjectured upon the life and destinies of nations. It has materials of tremendous power for the destruction of life; yet, in its most peaceful applications, to renew and invigorate the soil, it thus tends to shed a full measure of peace and prosperity upon ages to come. It has conferred a boon of great value on mankind in the production of chloroform and chloral, substances which were once costly and of no recognized value, but only of scientific interest. In its products, while it has contributed much to the adornment of our persons, it has also warmed, lighted, and ventilated our dwellings, purified our beverages and supplied us with beautiful utensils for our meals. While we are enumerating the boons conferred upon us by this science, the dim oriental outlines of the fabled genii rise to the recollection, by whose supernatural agencies, held in control by the magic lamp or ring, houses

were built and stocked, and many other wonderful works easily performed. Such a heaven-born power is ours in the science of Chemistry, the plaything of the child, the fascination of the student, the servant of man, obedient to his bidding who has knowledge, the true talisman of power. Surely the philosopher's stone would prove a poor possession compared with the riches placed at our command by this science.

It is the intention of this work to explain the leading chemical phenomena observed in nature, and to do so, as far as possible, without the unnecessary use and encumbrance of scientific terms of expression. In carrying out this design, the simpler plan appeared to be, to treat successively the air, the earth, and the ocean; by which means almost all that is of importance to be learned in the chemistry of nature, will come simply and naturally under discussion. Such a notice of the general principles of the science as is requisite to render the subsequent pages free from difficulty is added. Phenomena properly belonging to the department of Physics will here and there be noticed and explained, as all the branches of Natural Philosophy are intimately related and mutually aid in elucidating the philosophy of our globe.

PART I.—THE EARTH.

"HIS HANDS PREPARED THE DRY LAND." (Ps. xcv.)

"THE WORKS OF THE LORD ARE GREAT, SOUGHT OUT OF ALL THEM THAT HAVE PLEASURE THEREIN." (Ps. cxi.)

CHAPTER I.

THE INORGANIC CHEMISTRY OF NATURE.

WHEN an admirer of paintings walks through a long gallery in which are displayed the most famous works of a great artist, he stands, perchance, before one which more than all the rest attracts his attention, and becomes lost in the contemplation of its various excellences. The rich hues of the foreground become contrasted with the pale receding tones of colour on the horizon, and with these the deep transparent sky is exquisitely harmonized, the whole picture producing an impression upon his mind highly favourable to the skill of the painter. He goes away, and the impression remains deeply engraved upon his memory; yet if called upon to account for this impression by separating the individual peculiarities of the painting in the form of an analysis, probably not one spectator out of a thousand could execute the task! The

picture was agreeable to his mind as a whole, and not as a combination of various parts of different tints, and contrasted colours.

But if, on the contrary, a student stands wrapped in thoughtful admiration before the same painting, one whose own hand has laboured at the brush and palette, and in whose breast the aspiration after the highest honours of his art is nursed in hope, how different the effect upon his mind to that we have just been considering! Having been carefully tutored in the principles of the art, he is able to recognize in the work before him the various steps and processes by which the unity and harmony of the whole have been produced. He marks with a scrutinizing and admiring eye the careful manner in which the different portions of the picture are worked out so as to be in keeping with the terno of the entire work; and in various ways he is enabled to detect the development of the peculiar principles upon which the art of painting fundamentally rests. The other gazed upon the picture, and was pleased—he knew not why. This spectator also gazes upon it with gratification; but it is of a higher and more refined nature, simply because he is acquainted with the various truths which guided the artist in its execution.

Such is, in a word, the difference between "common" and "philosophical" observation, or, to use a more homely phrase, between "eyes and no eyes." The great majority of persons, when beholding the majestic landscape which the Divine hand has created, come under the first of these designations,—they are common observers. It is true they mark with real

and perhaps exalted pleasure the beauties of the scene, but they do not attempt to define the parts which in their union form the pleasing "whole." They see, but they do not analyze; or in other words, they observe the scene as a scene, but do not discover and separate from one another the various parts which enter into its composition. It is the privilege of him whose mind has been opened to receive the truths of science, when placed in a similar situation, to enjoy all the gratification produced by the contemplation of the scene before him in its entireness, and in addition, the pure and intellectual pleasure of distinguishing the operation of various laws by the means of which he is aware that the harmony of the landscape has arisen and is preserved. To the enjoyment of this privilege, in so far as the knowledge of the principal chemical phenomena of nature is concerned, it is intended that the present work shall assist the reader.

Place we ourselves then in such a scene. On all sides but one, the rugged forms of ancient rocks project into the sky, their summits capped with meagre herbage, and their sides the occasional resting-places of some mountain flower. The roar of a cascade, formed by the accumulated waters shed from the hills in the distance, comes every now and then upon the ear. Above is the blue stretch of an almost unclouded sky. As the eye travels toward the horizon through the opening already alluded to, it sweeps over many miles of fertile land adorned with trees or yellow with corn, and enlivened by an occasional traveller, or by herds of cattle, until it rests upon the blue line of the ocean in the extreme distance. Here let us take our

stand, and in the spirit of observation of which we have spoken, let us bring under review the interesting matters for chemical discourse presented to us by such a spot.

In so doing it is our intention to take up in succession the Chemistry of the inorganic, the animal, and the vegetable kingdoms of nature, so far as it can be conveniently considered under the three great divisions of our work, the Earth, the Air, and Ocean. An outline of many of the truths of Chemistry will thus be brought under notice; but for purposes of scientific information of a more profound kind, and for the more abstruse doctrines of the science, the reader will naturally seek elsewhere. The object in view is more humble; yet this work may fulfil a legitimate calling in provoking the desires of some minds to deeper investigation, and in other instances, in giving that peculiar interest in the objects of nature which arises from a perception of some of the intricate and beautiful machinery which directs and controls their movements.

Attractive as the possession of this knowledge appears, it is not to be acquired nor retained without a general acquaintance with some of the fundamental principles of the science; we propose, therefore, as briefly and simply as may be, to acquaint the reader with a few of their leading features.

Here our first attempt must be to reduce all material substances to their elementary or simple condition; our next to discover the laws by which the elements are governed in their behaviour one toward another. The ancient idea of the elements was, as is well

known, that there were but four—air, earth, fire, and water. But, in truth, none of these are elements. Air is a mixture, earth, and water are compounds, and can be split up into two or more essentially different materials: fire is only a condition of matter undergoing rapid chemical change.

What then is an element? It is a simple substance which a chemist is at present unable to split up, and out of which nothing essentially different can be obtained. Gold, silver, copper, and iron, when pure, are elements. By no treatment whatever can anything else but gold, silver, copper, or iron be obtained respectively from either. Therefore we call them elements. It may or may not remain for the science of the future to develop the truth or falsity of a view which has been entertained by the minds of some of the profoundest philosophers, as well as by those of the most imaginative alchemists, that all matter has a common origin; that, in fact, there is but one element, of which all the others are but modified forms.

Although we fail to analyze gold, it is very different with water. This we can separate or decompose into two elements, each having essentially different properties. A number of bodies once considered to be elementary have no claim to that character; they have been found to be compounds consisting of two or more elements. The number of elements at present recognized as such is sixty-four. They are for convenience divided into two classes,—metallic and non-metallic. The metallic elements comprise hydrogen, iron, zinc, tin, lead, mercury, copper, gold, silver,

platinum, &c., and are forty-nine in number; the non-metals are fifteen in number, and include oxygen, nitrogen, chlorine, phosphorus, sulphur, carbon, &c. All the gaseous elements can be condensed into liquids and solids, and, with sufficient heat, all solid elements can be changed into liquids and vapours.

Some of these elements are very abundant, and are of widest distribution; others, again, are so very rare as to be but very little known. Only four are met with in the air, and about thirty in water. The bulk of the earth, or at all events of its crust, consists of only eight elements. Silicon, aluminum, iron, calcium, magnesium, sodium, and potassium, united with oxygen, compose the primary rocks.

Indeed, when we come to consider the relative importance of each of these elements, we are lost in astonishment. Rest we our eyes upon the broad ocean, constituting, as it does, three-fourths of the area of our planet, we find pure water to consist of oxygen and hydrogen. If we turn to the animal and vegetable kingdoms, and point to the countless myriads of species and to the innumerable products of these kingdoms, how strange to discover that these are composed mainly of carbon, oxygen, hydrogen, nitrogen, sulphur, and phosphorus! The number of metals, too, employed in the service of man is very small.

Thus, while the forms in which material substances and organizations present themselves to our notice are of the most pleasing aspect and unbounded variety, and while the bodies themselves possess the most opposite and dissimilar properties, all are re-

ducible to a comparatively very small number of elements. The results of this arrangement are very striking. How surprising to find that carbon, which is one of the principal constituents of carbonic acid (or carbon dioxide, as it is now commonly called), diffused only in fractional quantities, even in the purest air, is the same with one of the chief components of the solid material of dense forests! How wonderful to learn that the millions of tons of wood contained in some of the primeval forests of the earth were actually, in a great measure, directly derived from this carbonic acid gas decomposed in the leaves!

A more remarkable vein of thought is opened up when it is stated that Chemistry has made us familiar with compound substances which are absolutely identical in the number and proportions of their elements, yet are as totally unlike one another in their natural properties—such as colour, smell and taste—as is the case with substances in nowise related to them.

Until lately our knowledge of the composition of the heavenly bodies was restricted to that obtained by a chemical examination of meteoric stones; but now, by the help of spectrum analysis, a good foundation has been laid of stellar and solar Chemistry. No element has, however, been met with that is not found upon this our planet. The unity of creation is thus seen to be as wonderful as is the accomplishment of astonishing variety out of few materials, which at the very outset Chemistry presents to our admiration.

In the Chemistry of nature oxygen occupies the most important position. It is the most abundant of all the elements, forming as much as 45 per cent. of the weight of the earth's crust, eight-ninths by weight of pure water, and more than one-fifth (23 per cent.) by weight of the atmosphere. Oxygen is a colourless, invisible gas, without taste or smell. It is possessed of the most extensive range of affinities; that is, it can enter into union with all the elements, with the single exception of fluorine. When oxygen combines with another body the process is called oxidation, and is always attended by heat, and often by light. Its connection with the vital functions of the animal frame, the purity of the atmosphere, the renovation of the earth and the necessities of mankind will come into consideration in different portions of this work.

Hydrogen, another important element, forms one-ninth of the weight of water, which is, indeed, an oxide of hydrogen. Like oxygen, it is a colourless, tasteless, and inodorous gas, and is especially distinguished as the lightest form of matter. It enters largely into the composition of animal and vegetable structures.

Nitrogen forms one of the chief constituents of the atmosphere. In appearance it resembles oxygen and hydrogen; that is to say, it is a gas without colour, taste, or smell. It, however, does not combine readily with other bodies, and is a very inactive substance, neither burning in air nor supporting combustion.

Carbon must also be mentioned, as an element

widely distributed, and as the very foundation of all vegetable and animal matters. It presents the appearance of a solid, but it forms combinations which are liquid, solid, and gaseous. In combination with oxygen it exists, in the air, as a gas, and in chalk, limestone, and marble, as a solid. Many of its compounds with hydrogen are liquid, and, together with oxygen and a little nitrogen, it may be said that the chief part of the woods and of the coal formation consists of carbon.

Such is a short and simple outline of the characters of the most active and abundant elementary substances entering into the composition of the animal and vegetable worlds. Other elements, like sulphur and phosphorus, are equally necessary, but they are present in smaller quantities. Nor must we forget silicon, aluminum, calcium, magnesium, sodium, potassium, and iron, which play so important a part in the mineral world. As we proceed we shall have successively to consider the numberless links of union which connect these together, and which, as a whole, constitute the wondrous scheme of the material creation.

If a polished piece of iron is left in the open air, and is slightly moistened, we all know that it loses its brightness, and that it is said to rust. Now, why does it rust? It is because it, as an element, has a strong attraction for the element oxygen; so much so, that when they are placed together under favourable circumstances, they will unite and join together so as to form a new substance—the rust. An unseen power draws the two elements together, and keeps

them by the closest bonds of a union so complete, that the properties of the iron as well as of the oxygen have completely disappeared. This power of attraction is called chemical affinity.

All the elements are influenced in a greater or lesser degree by chemical affinity, and so the iron unites with the oxygen. As a rule, the more unlike to each other, the stronger is the tendency of the elements to combine. Thus hydrogen and iron, both of which are metals, exhibit no inclination to unite, but oxygen and iron are strongly opposed to each other in their chemical properties, and they therefore combine with such force that the strongest effort is required to separate them.

We may briefly mention the laws under which chemical affinity acts, and by their simple but beautiful adjustments produce much of that beautiful harmony which we behold in nature. They are four in number.

1st. THE SAME COMPOUND (say water, or the oxide of hydrogen) POSSESSES AT ALL TIMES AN UNALTERABLE CONSTANCY OF COMPOSITION.

For example:—If we took a glassful of water from a wayside brook in England, another from the Ganges, and a third from some alpine torrent, we should find that after careful distillation, in each case the water from these three sources would possess precisely the same composition. Eighteen parts by weight of water would be found to consist of sixteen parts of oxygen to two parts of hydrogen. If, again, we wished to form water by uniting oxygen with hydrogen, we must take sixteen parts by weight of oxygen, and two

parts of hydrogen, to form eighteen parts of water: with other proportions the excess of the one or the other would remain uncombined. From these two experiments it would be manifest that pure water, wherever found, and however formed, is always the same substance, and is made up of the same component gases in the same relative proportions.

"Who hath measured the waters in the hollow of His hand, and meted out heaven with the span, and comprehended the dust of the earth in a measure, and weighed the mountains in scales, and the hills in a balance?" (Is. xl. 12.)

2nd. EVERY CHEMICAL BODY, IN UNITING WITH ANOTHER, DOES SO IN A CERTAIN DEFINITE QUANTITY OR PROPORTION, OR IN MULTIPLES OF THAT QUANTITY; AND THIS IS CALLED THE EQUIVALENT, OR COMBINING PROPORTION, OF THE BODY.

Thus, eight parts of oxygen can unite with one part of hydrogen; sixteen parts with two parts by weight to form eighteen parts by weight of water. Every element has then its proper combining proportion, by which is to be understood, in the words of the law, that "certain definite quantity" in which alone it will unite with other elements. These proportions or *equivalents* are mostly different from one another, while some interesting relations subsist among a great number of them.

The smallest quantity of an element in a free state is called a molecule; the smallest quantity in combination, an atom. One atom of hydrogen is the equivalent of one atom of chlorine; but two atoms of hydrogen are the equivalent of one atom of oxygen.

The atomic weights of a few well-known elements may be given :—

Hydrogen	=	1	Chlorine	=	35·5
Carbon	=	12	Potassium	=	39
Nitrogen	=	14	Calcium	=	40
Oxygen	=	16	Iron	=	56
Sodium	=	23	Bromine	=	80
Silicon	=	28	Silver	=	108
Phosphorus	=	31	Iodine	=	127
Sulphur	=	32			

Chlorine is a gas, bromine a liquid, and iodine a solid, at ordinary temperatures. Bromine has a combining number, or equivalent, intermediate between chlorine and iodine. This is shown in the following table :—

Chlorine 35·5
Bromine 80. $\frac{35.5 + 127}{2} = 81.5.$
Iodine 127.

Bromine is also intermediate in properties between chlorine and iodine. The same relation holds good between many other elements, as sulphur, selenium, and tellurium ; potassium, sodium, and lithium ; barium, strontium, and calcium.

3rd. WHEN AN ELEMENT UNITES WITH ANOTHER IN SEVERAL PROPORTIONS, THESE BEAR A SIMPLE RELATION TO EACH OTHER.

For example,—Oxygen unites with hydrogen in two proportions, thus :—

Oxygen 16 unites with 2 hydrogen to form 18 parts of water, but 2 of oxygen, or 2 × 16 parts by weight, further unite with 2 of hydrogen to form

34 parts by weight of peroxide of hydrogen. The proportion of hydrogen remaining constant, that of oxygen increases in the simple ratio of 16, 32.

4th. THE COMBINING QUANTITY, OR THE EQUIVALENT OF A COMPOUND SUBSTANCE, IS THE SUM OF THE COMBINING QUANTITIES OF ITS COMPONENT ELEMENTS.

For example,—Pure water is composed of one equivalent of oxygen, or sixteen parts, together with two equivalents or two parts of hydrogen. Add these together and we have eighteen as the combining proportion of water. Many examples of the practical importance in the arts of this doctrine might be given. If it were required to produce a certain weight of pure water, the law of combining proportions teaches us exactly how much oxygen and hydrogen we ought to use, so that the one shall be in exact combining proportion to the other, and so prevent our wasting either of these substances.

The immense works now in full operation as chemical manufactories, where many hundredweights of materials are used at one operation, would succeed very indifferently, if at all, were not this last law taken as the guide of all their proceedings. Oil of vitriol, soda, glass, soap, colours, alcohol, benzole, and a number of other substances, are now prepared in these works on purely scientific principles; and, were it otherwise,—as, indeed, it used to be when the laws of Chemistry were unknown—vast losses would in many instances take place, from one or other of the materials being employed in excess, or the contrary.

The harmonious regularity and order of the world around us are dependent upon these laws. There is

no admixture of substances and elements without a definite purpose, and without stability, in nature. The laws of chemical affinity are, however, not the only causes at work in the various combinations and decompositions that are continually taking place upon the earth. The relative mass of the acting substances and, especially, the comparative solubility, or volatility of the products formed, exert a very important influence on chemical changes. Every particle of which this earth is formed is held bound by the chain of these laws; they direct its behaviour towards other particles, and the result is that the "Chemistry" of nature, instead of presenting us with a scene of disorder and destruction, appears before us like some graceful structure, every part of which has its appointed place, every stone its niche, every bolt its proper resting-place, while the whole is of exquisite beauty and design. For this structure, strong and symmetrical, has been lavishly adorned by its Divine Architect with painting and with sculpture, which are perpetual sources of inquiry and delight to man.

When we have discovered the elements of which the round world and all that therein is are composed, we have indeed learned much of the Chemistry of nature. We can take up a stone and say, such and such substances form it; or we can point to the falling waters of the cascade and say, it is chiefly a compound of hydrogen and oxygen. But we can say more: we can declare that the elements which form all this lovely creation are subject to certain laws which can be determined with the utmost precision. This is

to know yet more of this interesting subject, but even this is not all! These fair blades of grass and these beauteous summer weeds, still beaded perhaps with summer-dew and the home of many happy insects, can tell us more if we but question them rightly. So, too, can the sunbeam tell us more, the sunbeam which finds its way into the dull factory, or the dark prison:

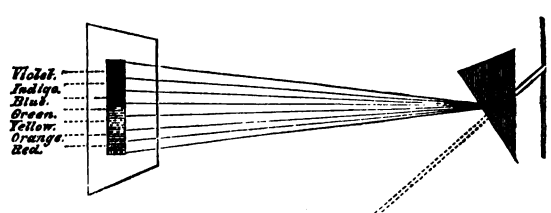
> "There are seven columns, massy and grey,
> Dim with a dull-imprisoned ray,
> A sunbeam which hath lost its way,
> And through the crevice and the cleft
> Of the thick wall is fallen and left."

The sunbeam that sparkles on the leaves of the forest, or the waves of the ocean, and that kindles a pale light on the quiet surface of some shadowed pool; the changeful clouds, the flints of the cliff, and the pebbles of the shore, are full of truths which are not summed up when we have numbered their constituent parts. No! there are wonderful forces in active operation on every side, so delicate in their mode of action and so subtle in their nature, that, until we are informed of their existence, it were scarcely to be wondered at if we exclaimed,—surely the knowledge of the elements and of the laws which they obey must comprise all that can be learned of the fundamental chemistry of creation?

If we were to ask, Why is this grass so green, that flower so fair, this breeze so balmy, and every object glittering with light? The sunbeam could supply the answer, and in the answer we shall find that pervading all nature, and performing the most im-

portant part in its operations, there are three distinct principles united in the sun's ray: *heat*, *light*, and *actinism* (radiant chemical power). Could we break up these bright streams of light, which are now pouring down on hill and dale, giving love, joy, and gladness to the scene, into individual rays, and by some process separate one from all the rest, we should discover all three in one,—that is, we should find it to consist of a ray of light, a ray of heat, and a ray of chemical force (actinism), each of these rays being itself made up of several others.

A simple experiment will prove that these three different classes of rays co-exist in a ray of sunlight. If on a bright summer's day we allow the rays of the sun to pass through a hole into a dark room, and then through a glass prism, we shall find, on holding up a white card at a certain distance from the prism, that the ray of light is broken up into a strip of various colours, called the prismatic spectrum. Here



PRISMATIC SPECTRUM.

the white beam is disentangled and reduced to the colours which compose it: the burning red, the vivid orange, the dazzling yellow, the brilliant green, and

the various shades of blue, viz., blue, indigo, and violet. These different tints blended together are, for convenience, grouped into seven so-called primary colours. This ribbon of beautiful colours exhibits to us, then, the light of the solar ray!

How are we to detect its heat and actinic force? If we take a very sensitive thermometer and place it first in the violet part of the streak, then bring it gradually downwards towards the red, it will be found that the mercury rises very little in the violet part, and very much in the red; strange to say, even a little beyond it, where we can see no colour, it will be highest of all! This shows us not only the heat of the sunbeam, but also the fact, that it exists chiefly in that portion of the prismatic spectrum where the red rays lie, and even beyond it where there is no light. This is accounted for by the rays of heat being less bent out of their direction by the prism, than are the rays of light.

The actinic rays may be exhibited in the following manner. A piece of paper on which some solution of nitrate of silver has been brushed, after it has been dried in the dark, must be placed in the streak of coloured light, care being taken that all other light is excluded from the room during the experiment. After a little time it will be found that the paper is blackened where the violet and indigo colours shone, and even beyond them, but less quickly, and to a very trifling degree, where the other colours are found. The truth thus discovered is that the nitrate of silver has been decomposed by the actinic, or chemical rays, which exist chiefly in the upper part of this

prismatic streak. The actinic rays are most bent out of their direction by the prism, for which reason they appear at the highest point of the spectrum. But the presence of the actinic rays may be shown in a still more striking manner if a small phial or narrow tube of glass, closed at one end, be filled with a weak solution of sulphate of quinine, and held in the dark space just beyond the violet. Though the liquid is only slightly bluish in white light, yet now a beautiful blue illumination will be seen on the side nearest the prism. Fluorspar, uranium glass, a spirituous infusion of the seeds of the Datura stramonium, as well as many other substances, present a similar appearance, supposed to be due to the conversion of actinic into light rays.

Thus we see that every ray pouring down from the sun consists of light rays, of heat rays, and of chemical rays. Need it be insisted upon that these exert an important influence upon the many chemical processes of nature? Indeed they are probably more important than we can at present imagine.

In the Mosaic account of the Creation the first step was the creation of light. "And God said, Let there be light, and there was light:" thus showing the importance of this principle. Light is now as necessary to life as it was then, when its first beams darted upon a yet unfashioned world "without form and void." To every animal and plant, and equally to man, the head of creation, light is indispensable and is inseparably connected with health, motion and activity. What a gloomy world were ours if a black sky without a single star were ever above the earth, leaving its

inhabitants in darkness and the shadow of death! The sad history of many a political prisoner will tell us how fatal to mind and body is the continued absence of the light of day. Little though it may be generally known, the flowers of various hues, the feathered tribes of glorious plumage, and the bright and beautiful among the insect tribes, and of those which inhabit the deep,—all owe their many-coloured aspect to the influence of light.

"Thy nimble pencil paints the landscape as thou goest." Is it not in the glowing atmosphere of the Tropics that we find the most splendid flowers and birds and insects? There, where the shadow of a cloud seldom flies over the bright and burning plains, where no fogs and vapours interfere with the power and brilliancy of the solar rays, every object is in holiday attire and gleams with colours such as we should seek in vain in our more temperate, but also in some respects more highly-favoured region.

Some remarks by the late Professor Edward Forbes, in his Report on the Molluscous and Radiate Animals of the Ægean Sea, exhibit this very clearly:—"The animals of Testacea and the Radiata of the higher zones are much more brilliantly coloured than those of the lower, where they are usually white, whatever the hue of the shell may be. Thus, the genus *Trochus* is an example of a group of forms, usually presenting the most brilliant hues both of shell and animal; but whilst the animals of such species as inhabit the littoral (sea-shore) zone are gaily chequered with many vivid hues, those of the greater depth, though their shells are almost as highly-coloured as

the coverings of their allies near the surface, have their animals, for the most part, of a uniform yellow or reddish hue, or else entirely white. The chief cause of this increase of intensity of colour as we ascend, is doubtless the increased amount of light above a certain depth." The sea-weeds and fish which have their abode near the surface of the water are far more beautiful than those which are found deeper down; and where the finny tribe live at the bottom, or at depths where a mere glimmer of light is all that distinguishes day from night, they become nearly colourless. On a future page it will become necessary to enter more fully into the chemical influence of light upon the vegetable world, where it will be found that the structures of plants are principally formed by its agency. Inseparably connected with light, in the phenomena of nature, is Heat. It is this which assists to call into activity the germ of life lying dormant in the seed; which bids the insect's egg awake; which breaks up the hard surface of the ice-bound field, and allows innumerable cold-imprisoned plants to bud; which clothes the forest with its myriad leaves, ripens the green untempting fruit, and makes all creation rejoice. All the day long the sun pours down upon the earth unfailing streams of this life-giving principle, which then become diffused into the surrounding air, making the breeze soft and warm, or penetrate the soil whence they again in part disperse into the air at night, or so soon as the sun has left us. Every object we behold is influenced more or less by heat. This nettle and that buttercup; the leaves and stems of one all covered with hairs, the

other polished and glistening, are both affected by the warm summer rays, but not equally. The nettle, being rough, is a good radiator, and therefore loses heat faster than the buttercup, which is smooth and a bad radiator; but then the nettle is also a better absorbent of heat. Undoubtedly this difference of properties of heat was not appointed in vain.

But more than this: while every flower that blows is dependent upon warmth for its expansion and the perfection of its various functions, flowers differ from one another in the use they make of it. Some absorb much heat and with great rapidity, others less and but slowly. Even the scents of flowers are not without their influence upon the air, returning some of the warmth borrowed from the sun's rays. Tyndall has shown that the vapours from the aromatic oils contained in the flowers, although emitted in quantity too small to be weighed, are capable of absorbing and emitting many times more heat than the air. Thus, the vapour from pachouli absorbed thirty times as much heat as common air, the rose thirty-six times, lavender sixty times, cassia one hundred and nine times, and aniseed three hundred and seventy-two times. So then the very fragrance of flowers performs a definite mission, and assists in diffusing warmth through the surrounding air, and warns us against the free use of certain scents in a close warm room.

Yet other duties, but of a more momentous character than any indicated, are performed by the heat of the sun's rays. It is the grand agent by which currents are produced in the air. How little do we

remember that the summer breeze which fans our cheek, the wind which propels our ships, or the storm which upheaves the oak of the forest, are alike set in motion by the subtle beams of the sun! So also is the circulation necessary for the preservation of the purity of the atmosphere sustained: thus are the clouds wafted so as to drop their precious freight on our thirsty fields: thus can man spread canvas and lend wings to his ships,—all as a consequence of this warm flood of sunshine in which the insect basks, and the landscape lies bathed and asleep! The heat of the sun likewise brings about the evaporation of water, and thus lifts it into the air, or dissolves the vapour which, when condensed, comes down as the grateful shower to fertilize our land. Also, since chemical changes of all kinds go on much more rapidly at high than at low temperatures, the heat of the sun is largely concerned in the chemical phenomena constantly taking place throughout nature.

> "Sunbeam of summer! oh, what is like thee,
> Hope of the wilderness, joy of the sea!
> One thing is like thee to mortals given,
> The faith touching all things with hues of heaven."

Light, heat, and actinism, these three! It is at present impossible to explain the real nature of the actinic force. We must rest satisfied by describing it as that power in the sun's ray which works the chemical changes taking place in bodies exposed to the sunbeam—as present also in the moon's rays —and produced, together with heat and light, in various kinds of combustion. The trees of the forest,

as well as the pale and lowly lichens which cluster on their bark, or the modest violet which graces the ground at their feet, owe their health and vigour, nay, their very existence, to the actinic rays. Intercept them, and plants become sickly and die, as we shall yet learn. Even more surprising is their influence upon inanimate bodies! It is impossible to expose any solid substance, of whatsoever kind, to the sun's rays without its undergoing some change in consequence of the operation of these rays upon its surface. Marvellous as it may appear, light can actually be bottled up for use. Take an engraving which has been kept for some days in the dark; expose it to the influence of bright sunshine for fifteen minutes; lay it on sensitive paper in a dark place, and at the end of twenty-four hours it will have left an impression of itself on the sensitive paper, the whites coming out as blacks. If exposed for a longer time, say an hour, till thoroughly saturated with sunlight, the image will appear much more distinct. Thus there seems to be no limit to the reproduction of engravings. Take a thin tube lined with white, let the sun shine into it for an hour, place it erect on sensitive paper, and it will give the impression of a ring, or reproduce the image of a small engraving and of a variety of objects at pleasure,—say feathers, figured glass, or porcelain. Take, moreover, a sheet of paper which has been thoroughly exposed to the sun, seal it up hermetically in a dark tube, and the paper will retain the light so effectually, that after two weeks, perhaps even longer, it may be used for taking photographs.

In the beautiful art of photography, the powerful and rapid action of the actinic rays is seen to advantage. Nature's own pencil may be employed to depict itself—the fairest landscape imprints its own image upon the surfaces of metal or paper; the most minute points of detail are thus preserved to us, and the wanderer in foreign climes needs little exertion of his own to store his portfolio with pictures drawn by the sun, which on his return may often serve to bring to his recollection scenes and objects far distant.

At Greenwich and other observatories the varying heights of the barometer and thermometer are self-registered continually by employing the actinic power of light; other meteorological phenomena are also recorded by the same means. The details are too complicated to be easily understood; the application relates to magnetical observations by little mirrors, placed upon the needles, which reflect the light on a sheet of prepared paper. Thus, when the needles move, they cause the reflected light also to move a certain distance upon the paper, and wherever this light falls, it leaves its mark in the discoloration that instantly takes place. Objects in the microscope have been beautifully and accurately copied by casting the images on prepared paper. Hitherto we can only be said to have produced pictures of one tint; but some singular experiments have been made, and are still in course of prosecution, which seem to indicate that in time it may be possible to produce perfect pictures, each object being represented in its natural colours.

"The glorious sun, the centre and soul of our system, the lamp that lights it, the fire that heats it, the magnet that guides and controls it, the fountain of colour which gives its azure to the sky, its verdure to the fields, its rainbow hues to the gay world of flowers, and the purple light of love to the marble cheek of youth and beauty." (Brewster.) As we proceed we shall have occasion to refer to its varied influences in the different kingdoms whose Chemistry we propose to consider.

But the sunshine, after all, only forms one of several agencies which combine together to give life to and preserve the many beauties of our landscape. The earth, the grass, the trees, yon shining river and those sailing clouds, could they be again interrogated, would disclose to us yet another agent which influences them all, and is for ever darting from and to them, silently and unseen, assisting in all the phenomena they exhibit, and consequently intimately concerned in the various processes of the chemistry of the Creation. This agent is Electricity. This wonderful principle passes incessantly through the soil on which we tread, influencing in various ways its component parts. Every blade of grass is sensible of its passage through its juicy cells into the air, and every leaf and every tree is constantly either parting with it, or receiving it and conducting it to the soil. It pervades the animal frame, so that in the quack language of the day, electricity is life. The wide atmosphere is a grand receptacle in which immense quantities of it are stored. No chemical change can occur without electricity being involved in the process.

In its applications to the purposes and wants of man, electricity excels all other forces. By its aid, in the electric telegraph, we can communicate in a moment with the ends of the earth. We can even print by electricity, so that news can be communicated with a rapidity which almost transcends belief. In the word electricity, we sum up "the light of the future." How common is the observation now, "I must examine this or that by daylight before I can judge of its colour or texture." No need of this with the electric light, which will no longer be confined to lighthouse purposes. All the clocks of a country may be regulated by means of electricity, and, being connected with a standard instrument, will indicate precisely the exact time.

In addition to the forces already enumerated, magnetism also holds a high place. Just as electricity may be made to produce heat, light, and magnetism, so magnetism may be employed to produce heat, light, and electricity. The magnet forms the basis of the telephone, that wondrous instrument invented by Professor Graham Bell, by which not only musical sounds, but articulate speech, is made to cover astonishing distances. But beyond the mention of these forces and that of gravity, we shall not further enter.

Thus, standing on this point which commands a view of the whole of the scene before us, we have found that a number of subtle principles, or forces, have been exhibited to us as concerned in the countless phenomena which are taking place so silently and imperceptibly around, above, and beneath us.

All nature owns their sway. They are the ministers of God, and do His pleasure.

"There is a power
Unseen, that rules th' illimitable world,—
That guides its motions, from the brightest star
To the last dust of this sin-tainted mould;
While man, who madly deems himself the lord
Of all, is nought but weakness and dependence.
This sacred truth, by sure experience taught,
Thou must have learnt, when wandering all alone;
Each bird, each insect, flitting through the sky
Was more sufficient for itself than thou."

THOMSON.

CHAPTER II.

CHEMISTRY OF THE LAND.

"IN HIS HAND ARE THE DEEP PLACES OF THE EARTH: THE STRENGTH OF THE HILLS IS HIS ALSO" (Ps. xcv.).

STANDING on this elevated spot we may take a survey of the scene before us. All is still; the breeze has died away, the air is now clear and without a cloud, and the ear listens in vain to catch a sound beyond the low and fitful rushing of those foaming waters, which, as they leave their rocky channel and flow through the fields beneath, again become silent and roll noiselessly into the sea. The shepherd's flock lies under the shadow of the overarching elm-tree, the cattle are standing in the shady hollow by the river-side, and the cowherd himself stretches his length lazily upon the soft grass on the bank. These green meadows, so fresh and luxuriant in their appearance, seem also asleep. The humble and soberly-arrayed flowers which bedeck the soil lift up their gaze to the light, and seem athirst for a refreshing shower. Although it is midday, and every object is bathed in sunshine, all is so quiet and so motionless that the repose is like that of the night.

We may return home, and on another opportunity

THE SCENE.

revisit the spot. If we go in Autumn we shall find over hill and valley rich lines of purple, gold, and brown; the earth has yielded its increase, and the fields, bared of their waving burden, look empty and naked. If in Winter, the waterfall is adorned with pendants of ice, the surface of the river is hard and solid, and a white garment of snow envelops the whole face of the landscape. With these natural changes we are made familiar by the continual round of the seasons; but beyond these, to the unscientific observer, it would appear that all things continue as they were. From year to year the hard lineaments of the rocks, and the rounder figure of the hills, are as familiar to our eyes as the well-known faces at the fireside, and the elastic sod seems in all respects the same as that on which we danced in childhood.

Is it, however, so in reality? Are there no changes taking place around us of a different kind to those of the seasons? In truth there are, and those of a most important kind. Chemical and mechanical forces are in ceaseless operation, the tendency of which is to bring down to the dust of the earth the hardest of those proud cliffs, now looking so strong and enduring. The substance of these rocks is gently crumbling away, and falling in fine particles, to become united with that of the plains at their feet. The greensward, though apparently the same, is in reality not so, even from year to year; its materials are being constantly removed, altered, and re-deposited. The air we breathe is incessantly altered in composition, and restored again, and its particles are in constant com-

motion and change of place and condition. The ocean is the scene of similar mutations.

The face of the earth is for ever renewed, altered, and re-formed. Generations of men, animals, and plants, perish and pass away, and with the fall of each, the constituents and character of the surface perpetually vary. All is in process of change; yet all presents the appearance of a profound repose. All things are working together and without cessation, even in the natural kingdom, and for good. The chemical energies know no such condition as quiescence in nature. They never pause; the cessation of one process is only the commencement of another; there is no absolute rest. They could cease from action only when they had reduced the whole earth to a smooth, level ball; and all that it contains to a certain fixity of composition. But there are wise counteracting causes which forbid such a result, and these very laws of change often also re-act upon themselves, so that the real condition of nature is an equilibrium—an equilibrium, however, which is preserved by continual efforts on each side to upset the balance.

This is a strong expression of the facts silently presented to us even in such a quiet scene as we have been contemplating. And it is necessary to offer them with one qualification. Many of the changes thus ceaselessly occurring are absolutely inappreciable by the ordinary tokens: thus, Chemistry alone can tell us that the atmosphere is constantly undergoing changes of addition, subtraction, and restitution to an enormous amount; but the senses

cannot directly discover it. And with regard to the surface changes, the amount of alteration at any one time is minute, and the extent can only be measured by a long lapse of years. It is important therefore to remember that these changes are in constant progress under our eyes, however silent and imperceptible may be their occurrence. By little and little the beautiful fabric of our globe gets out of repair, and is repaired again; its features the meanwhile not sensibly altered, although continually altering. The rocks which shut in the valley in which we have placed ourselves are dropping to pieces. Could years be compressed into hours we should see their rugged sides crumbling down in great heaps; and could to us a thousand years be as one day, we should probably see many of them swept away and levelled to the ground before our feet.

It will therefore be interesting to inquire by what processes these destructive, wearing-down operations are accomplished? The main agents are water, carbonic acid, and oxygen.

Water acts in two ways, as a mechanical agent and as a solvent. In mountainous regions, where the force of running water is very great; in the ocean, or in any other place where a large mass of water wears the stones or sweeps along the earth, the mechanically-destructive powers of water are very great. At the Falls of Niagara, for example, geologists are considered to have proved that in the course of time the river has cut its way back through several miles of rock, and is still gradually receding, it is said, at the rate of a foot a year. In so doing it is difficult even

to calculate how many millions of tons of solid rock the water must have worn away in the time occupied in the removal of the Falls from their previous to their present position. The manner in which this process of disintegration is effected is described by

BIRD'S-EYE VIEW OF NIAGARA FALLS AND COUNTRY AROUND.

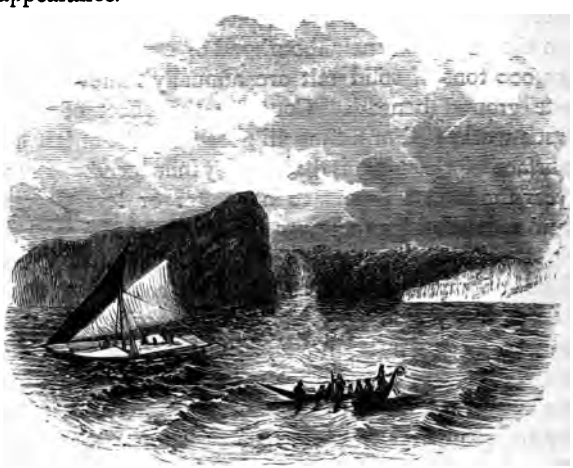
Sir C. Lyell in the following terms:—"The waters, after cutting through strata of limestone, about fifty feet thick in the Rapids, descend perpendicularly at the Falls over another mass of limestone, about 90 feet thick, beneath which lie soft shoals of equal thickness, continually undermined by the action of the spray driven violently by gusts of wind against

the base of the precipice. In consequence of this disintegration portions of the incumbent rock are left unsupported, and tumble down from time to time, so that the cataract is made to recede southwards. The descent of huge rocky fragments of the undermined limestone at the Horse-shoe Fall in 1828, and at the American fall in 1818, is said to have shaken the adjacent country like an earthquake."

Very little thought is necessary to convince one that the fine particles of solid matter which form mud are produced by the mechanical waste of the land. Each shower of rain as it falls removes something off the surface of the land. This removal is called by geologists denudation, since the rocks are often made nude in the process; and when accomplished by a fall of rain, the denudation is called pluvial (*pluvia*, rain). It has been estimated by Professor Geikie that the river Thames discharges annually 1,865,903 cubic feet of sediment! But even this is not all. Water possesses the power of dissolving certain gases and salts. Many of these are in simple solution, and may be obtained with all their characteristic properties by mere evaporation. One of the most interesting examples of the kind fell under the observation of the writer in the salt-districts of Cheshire, and it is probably without a parallel. Near Northwich the rocksalt occurs in magnesian-limestone. The principal deposit is found in two beds, situated one above the other, separated by about 30 feet of clay and marl intersected with small veins of salt. The two veins together are about 60 feet in thickness, 300 yards broad, and a mile-and-a-half long. Some of these

are worked in the usual manner by mining, shafts being bored down to them, and the salt being then dug and blasted out: but ordinary table salt is obtained in a different manner. In various parts of the district what are called brine springs have been found; these are simply springs of water charged with salt and are naturally formed by water filtering through the soil to the salt beds, there dissolving a portion of the salt, and then being pumped up by machinery. From this brine table salt is procured by boiling it down in large flat iron pans, in which it crystallizes and from which it is ladled out, poured into wooden moulds, and dried. Thus large portions of the salt-beds disappear under the dissolving influence of water. In the immediate neighbourhood of one factory some 52,000 tons of solid salt are annually removed from the ground beneath. Conceive the effect of many such works! For a time all goes well, but at last the surface of the earth is disastrously influenced. Every year the land subsides to a greater or less degree, and as it subsides the river Weaver encroaches upon it, converting what was formerly meadow-land into a lake of many acres in extent. What was once a pleasant walk is now a pleasant sail, for it is covered with deep water. Cottages, landmarks, footpaths, are all gently, but surely, becoming submerged by the sinking of the land. Buildings are rendered insecure by the gradual failure of the foundations. Some are bound together with iron girders to keep them from falling. Tall chimneys present a most ludicrous appearance; many of them lean as much as the leaning tower of Pisa, and are only kept from tumbling

down by strong iron rods which are attached to them to hold them up. In short, the whole district around the brine springs is settling down at a rate which is proportionate to the amount of solid salt dissolved by the water, so as to fill up the vacuity left. Water has performed a curious office also for the rocks of one of the islands of the Pacific. The rocks are composed of crystallized carbonate of lime, perhaps originally coral, but by exposure to the air and by the percolation of water the loose particles of calcareous matter have been washed away, and the whole mass presents in consequence a very brilliant crystalline appearance.



THE CRYSTAL ISLAND.

The island is represented in the cut.

The baths of San Philippo, in Tuscany, are men-

tioned by Sir Charles Lyell as consisting of waters containing so much bi-carbonate of lime in solution as to yield a stratum a foot thick in four months. In a pond into which they are conducted, they have deposited a solid mass 30 feet thick, in the period of twenty years. The mineral contents of the water are turned to profitable account by the establishment of a manufactory for medallions. Moulds exposed to the spray of the falling waters are coated over in a short time with a beautifully white crest harder than marble.

Other instances of the extensive influence of the dissolving power of water may be mentioned. A gallon of Thames water contains about 21 grains of salts in solution: according to Professor Prestwich, about one ton per minute of saline matters in solution is discharged by the Thames at Kingston. The water of the river Dee, of Aberdeen, which draws its supply from a granite district, contains only about three grains of saline matter per gallon. The solid matters in solution in sea water are equal to $3\frac{1}{2}$ to 4 per cent. Most of the salt is in the form of common salt, and is equal to some 2,000 grains per gallon.

It is only when we consider the body of water conveyed away by even so small a river as the Thames, that we attain to anything like a comprehension of the power of small things. Then we arrive at astonishing totals. In the course of a twelvemonth the river carries away in invisible solution from its basin above Kingston, 548,230 tons! The mechanical influence of water upon our sea-coasts will receive notice in another part of this work. But we must

not forget the immense expansive force exerted by water when passing from the liquid to the solid state. Sometimes it may be seen in the bursting of a water-pipe in the frost, or in the splitting of stones through the freezing of the water in its fissures. But generally the changes occur under conditions which allow of no opportunity for observation. To give an example of this energy we may confine a column of water not thicker than a goose-quill in an iron bottle fully half-an-inch thick; when such bottle is closed with a screw iron stopper and the water frozen by the help of a freezing-mixture, the rigidity of the iron is powerless against the expansive force of the freezing water, and the bottle is burst.

Besides all this, we must take into account the effects of falling water. Large deep basins are often hollowed out of the hard rock by the friction of water falling from a height. In some cases detached portions of stone, remaining for a long time in these hollows, and being continually subject to a rotatory movement, at last become rounded into balls of considerable size. Such stone balls have been found beneath several of the water falls in the English lake district. We must pass by, however, the simply mechanical and solvent powers of water as concerned in the phenomena of nature, to the more important considerations of its chemical effects.

As a solvent of carbonic acid and of oxygen, water plays its part as a chemical agent. Although carbonic acid is so feeble an acid, it is found that felspar which forms a considerable part of the hard granite rocks, is slowly affected by water containing it in solution.

D'Aubuisson relates that the granite country of Auvergne and the Eastern Pyrenees is often so much decomposed, that the traveller may imagine himself upon large tracts of gravel. And to show that this process, under favourable circumstances, may be of sufficient rapidity to be observable in a few years, the same author mentions, that in a hollow way, which had been only six years blasted through granite, it was found on examination that its walls were so much decomposed by the influence of carbonic acid, that the solid rock to the depth of 3 inches was in a crumbling condition. Dolomieu calls the peculiar effect produced by this gas a disease of the granite! In such districts, masses of granite are found which look quite solid, yet when touched by the hand or trodden by the foot of the traveller fall to powder. Such is the influence of this decomposition in granite that it is found in the quarries at Dartmoor, to the depth of 50 or 60 feet, to be more or less decomposed. Consequently this granite, which is called surface granite, is less durable than that obtained beyond the influence of decomposition. The construction of granite is peculiar. The mass is white or grey, and consists of quartz; the little bright flaky crystals are called mica, and the oblong, flesh-coloured crystals in common granite are called felspar. When mica is absent from granite, and hornblende substituted, granite is called syenite: of this the Cleopatra Needle is composed.

The granite used for the Nelson Monument, and employed generally for such purposes was obtained from a depth below the influence of atmospheric de-

composition. The most curious and grotesque results often arise from the wearing effect alluded to. Many of the strangely-fashioned stones which antiquaries take pleasure in considering to be the work of Druid hands, have been chiselled by these decomposing powers alone. Sir H. de la Beche mentions a singular specimen of such natural sculpture as occurring at a point on the Isle of St. Mary, Scilly

THE KETTLE AND PANS.

Islands, called the "Kettle and Pans." This curiosity consists of several basins, apparently hewn out of the rock, some of which are 18 feet in circumference, and 6 in depth. It is believed they are entirely attributable to the operation of the causes in question.

It is a singular fact that we are indebted for all our porcelain to the results of the decomposing agents just described. All our earthenware, from the commonest jug to the house-tile and flower-pot, is in like manner produced from a material which is formed by the influence of water, air, and carbonic acid upon rocks of various kinds, but all more or less agreeing in composition as to their chief ingredients. In certain districts in Devonshire and Cornwall there exist rocks of a fine white granite, which exhibit the decomposing effect of these agents in a remarkable manner. At Shaw, a few miles from Plymouth, the surface for hundreds of acres consists of decomposed felspar, in a state resembling flour. When purified and baked, it forms a fine porcelain. On the surface, and for a considerable depth into their substance, the rocks are altered to a soft matter resembling mortar. This is collected and washed; the water which comes from the washing of it, being of the colour of milk, in consequence of its containing a quantity of white earthy substance suspended in it, is conducted into tanks, and in its passage through several reservoirs deposits this white earthy matter at the bottom. The tanks are then emptied of water, and the white deposit being removed, and dried in the open air, and subsequently more completely by a drying-stove, constitutes the beautifully fine white *clay* employed in the manufacture of porcelain. Not less than 10,000 tons of this white clay, thus derived from the decomposed material of the granite rock, is imported annually for the use of the potteries. Its chemical composition—the composition in great part of our china cups and

ornamental ware—is alumina (the basis of common alum), silicic acid, a little alkali and lime, and in the unburnt state, a large proportion of water, together with a variable amount of sand. The Chinese, as well as ourselves, employ the same material for the manufacture of their exquisite porcelain.

Clay of every description is produced in the same manner; yet it is only the best china which is of a pure white colour. Common earthenware is more or less yellow, brown, or red from the presence of oxide of iron, a colouring matter which communicates its stain to the clay.

The granite often contains crevices of some width more or less open and full of beautiful crystals, partly of the minerals of which the granite is made up, partly of foreign minerals valuable as yielding metals. They are then called mineral veins and are the object of search to the miner.

Surprise has often been expressed how mines of silver have been discovered in such extraordinary situations as some of those on the bleak summits of the Cordilleras of South America. But a little consideration of the effects of the agents we are speaking of, would, in a simple manner, have removed the difficulty. Silver, it is well known, resists the action of the air and weather, while the rocks in which the veins of the metal lie are readily decomposed and worn away. The natural result is, that in process of time, the veins of silver are left standing out from the surface of the cliff, which has been worn away all around them, and so the first wanderer that passes by finds a mass of the precious metal sticking out of the

rock. We are told by Mr. Darwin that the celebrated and rich mine of Chanuncillo, from which silver to the value of many hundred thousand pounds has been raised in the course of a few years, was discovered by a man who threw a stone at his loaded donkey, and thinking that it was very heavy, he picked it up, and found it full of pure silver. The vein occurred at no great distance, standing up like a wedge of metal.

That vast supply of gold which has been recently discovered in the sands of rivers, and in the valleys of Australia, California, and British Columbia, is another indirect result of the disintegrating influences of air, carbonic acid, and water. This noble metal being scattered in small particles through the substance of various ancient rocks, is at length, by the constant wearing down of the latter, set loose, and is then washed down and borne by mountain-torrents to a distance from its original position. Its great weight renders it easily separable, simply by washing, which carries away the lighter particles of sand and mud, leaving the heavy metal behind.

In Egypt, the student of the Chemistry of nature is presented with a highly remarkable illustration of the operation of these causes of waste and decay. In countries where the atmosphere is charged with moisture and rain is frequent, or wind prevalent, the destructive effects of these agents upon the strongest buildings soon become evident. This is strikingly exemplified in the Delta and the rest of Lower Egypt, which are affected by the exhalations arising from the neighbouring sea. The consequence is, that Memphis, which was formerly the celebrated capital of the

whole kingdom, Heliopolis, Sais, and other important cities, are now mere heaps of ruins. The granite obelisks at Alexandria are partly illegible through the corroding influence of the atmosphere. On the contrary, in Upper Egypt, the monuments, unaffected by the inundations of the Nile, and the tombs, exhibit no signs of decay after the lapse of many centuries: much, indeed, of the colour with which they were originally decorated still remains. The black bricks made out of the mud of the Nile and dried in the sun, some of which have been exposed to the open air for thousands of years, as is proved by their bearing the name of Ramses Miamun, who is supposed to have reigned in the fourteenth century before the birth of our Lord, still retain their original hardness and firm position in the temples, pyramids, and tombs for which they have been used, together with all their architectural ornaments.

Materials thus worn down by the chemical agency spoken of are called *débris*, a word which signifies a wreck, or waste of anything, and is therefore very appropriately employed to designate the wreck or waste of the cliffs under the slow but certain powers of the Chemistry of nature. *Débris* generally collects at the base of the cliffs, by the decomposition of which it has been formed, and does so generally in the form of conical heaps, the upper point of the cone resting against the side of the rock. Sometimes, and particularly in the stupendous mountains of South America, great masses of this "waste" slide down into the valleys like huge avalanches, overwhelming every object in their course. It is at the base of these mighty moun-

tains, that the "waste" rises sometimes to the enormous height of 2,000 feet—the accumulated result of the action of water, carbonic acid, and air, for centuries. But these heaps, vast as they are, are only the visible monuments of the power and extent of

DÉBRIS AT THE BASE OF CLIFFS.

these destroying agents, and as such only represent a very small amount of the *débris* actually produced. The greater part of it is swept down by rain and borne away to be deposited in the last resting-place of the rivers, whether that be lake or ocean, into which it

ultimately falls. The granitic summits of Mont Blanc, and of the adjoining range, exposing a vast surface to the atmosphere, are of course peculiarly exposed to the destroying powers in question. Glaciers and avalanches sweep down from their sides the crumbling particles, in the form of mud, pebbles, and *detritus*, or crushed rubbish, and thus supply the impetuous river Arne, which descends from these lofty regions. "Scarcely," says Sir C. Lyell, "has the Rhone passed out of the Lake of Geneva before its pure waters are filled with sand and sediment by the Arne. The Rhone afterwards receives vast contributions of transported matter from the Alps of Dauphigny, and the volcanic mountains of central France; and when at length it enters the Mediterranean, it discolours the blue waters of that sea with a whitish sediment for the distance of between six and seven miles." The Red River of Louisiana is so full of the disintegrated particles derived from a region of red porphyry rocks through which it flows, as to have received its name from the fact; the river deposits its sediment on its banks in regular layers of red. Many other rivers are coloured blue, black, yellow, and brown, from similar causes. The very names of the Ganges and Nile are so associated with the fertilizing influence of the mud they convey, as scarcely to make it necessary to allude to them in illustration of this subject. But it may be mentioned as affording us somewhat of an illustration of the amount of effect possible to be thus produced, that it has been calculated that the former of these rivers, in the course of a single year, carries down many millions of tons of mud—that is, of disintegrated rock,

The sediment thus carried down is spread upon the bottom of the seas, into which it is discharged, there forming a layer of yearly increasing thickness.

The more wild and rugged the scenery of nature, the more certainly and rapidly do these agents, first the chemical forces, and next the mechanical, combine to carry on the work of disintegration and, if we may so call it, decay. In the gorgeous scenery of the Andes, where rise bare and precipitous hills of porphyry, pinnacles and fortresses of rock, more wild and grand than painter yet conceived, and where violent conflicts of the elements are not unfrequent, it may be imagined that this process goes on with unusual rapidity. The following passage from the journal of Mr. Darwin conveys the impression with peculiar force :—

"The rivers which flow in these valleys (of the Cordilleras) ought rather to be called mountain torrents. Their inclination is very great, and their water the colour of mud. The roar which the Maypu made, as it rushed over the great rounded fragments, was like that of the sea. Amidst the din of rushing waters, the noise from the stones, as they rattled one over another, was most distinctly audible even from a distance. This rattling noise, night and day, may be heard along the whole course of the torrent. The sound spoke eloquently to the geologist; the thousands and thousands of stones, which, striking against each other, made the one dull uniform sound, were all hurrying in one direction. It was like thinking on time, where the minute that now glides past is irrecoverable. So was it with these stones; the ocean is

their eternity, and each note of that wild music told of one more step towards their destiny.

"It is not possible for the mind to comprehend, except by a slow process, any effect which is produced by a cause, repeated so often, that the multiplier itself conveys an idea not more definite than the savage implies when he points to the hairs of his head. As often as I have seen beds of mud, sand, and shingle, accumulated to the thickness of many thousand feet, I have felt inclined to exclaim, that causes, such as the present rivers and the present beaches, could never have ground down and produced such masses. But, on the other hand, when listening to the rattling noise of these torrents, and calling to mind that whole races of animals have passed away from the face of the earth, and that during this whole period, night and day, these stones have gone rattling onwards in their course, I have thought to myself, Can any mountains, any continent, withstand such waste?"

The material washed down by rivers after it has been disintegrated by chemical forces and deposited under water either in the sea or in a lake is called *alluvium*, when in the course of natural events it is at length raised above the surface of the water, as when, by some circumstance, the course of the river becomes altered, and the matter it formerly carried towards the sea becomes exposed. Alluvium is thus literally land, which has been added by the wash, or flow, of water. It constitutes the soil of many valleys, such as that we are contemplating, and consists of sand, gravel, stones and fine sediment, or mud, most of

which may be often traced back to their source in the mountains, or hills, in which the rivers rise.

And so, too, when a river approaches the sea, its speed slackens on account of the inclination of its basin being diminished; consequently it deposits more or less of the matter which it holds in suspension. If the sea near the river's mouth is not disturbed by currents, the alluvium may accumulate and spread itself in the form of a fan. The old name, "Delta," is now in common use to designate these outspread alluvial deposits.

Enough has been said to exhibit the powerful influences which are incessantly at work in altering and destroying some of the most apparently unchangeable objects which surround us.

CHAPTER III.

CHEMISTRY OF THE SOIL.

THE law of change, illustrated in the last chapter exclusively by its influences upon the sterner features of our landscape, the rocks and mountains, prevails especially in the soft layer of brown earth which we find on the surface of the field. The whole mass of vegetable mould is a mixture of substances continually altering and undergoing change, and is of interest to the student of the Chemistry of Creation.

The soil which covers so extensive a portion of the earth's surface consists of materials which differ essentially according to the geology of the district, but which comprise the disintegrated particles of rocks, sand, clay, and calcareous matters, and the remains of animal and vegetable bodies. It is that reservoir from which vegetables for the most part directly derive their sustenance. From the soil come the pleasant fruit for man's refreshment, the grain for his support, the herb for the relief of his sufferings, the root for the colouring of his garments, and that extensive list of useful products which manifests the beneficence of the Creator. While the depths supply man with materials for his utensils, for his bodily comfort, and even his luxuries, the soil (together with the air) yields all that animate creation can require for the support of life.

" Speak no harsh words of earth ; she is our mother,
And few of us, her sons, who have not added
A wrinkle to her brow."

The chemical processes concerned in the production of mineral and vegetable soil are essentially different. The mineral soil consists for the most part of the wash of rocks; the vegetable, of the residues of plants. Generally the two occur in admixture, and thus produce the fertile soil, but it should be remembered that the natural processes which produce the alluvium (p. 58), and those which form vegetable soil, or mould, are quite different. The subject is interesting, and worthy of further examination.

Let us travel back in thought to the time when the scenery we are now beholding exhibited a very different aspect. Yonder river now rolling down a channel, some twenty miles long, and emptying itself into the sea, was then an impetuous torrent, not a third of its present length. Those green and fertile plains which form the smooth bottom of the valley were then submerged beneath the waters; and from the spot on which we now stand, the eye, as it looked across to the rocks and hills on the other side, would have seen only tossing waves in the place of waving corn. In a word, this valley did not then exist; it was a beautiful bay, the waters of the sea washing the foot of the hills and rocks which now hem it in; and at its upper end the torrent, formed by the water-shed of the distant mountains inland, and of the hills around, poured into the sea, bringing down mud, gravel, and stones incessantly.

Time went on; the level of the sea-bottom was raised, the waters gradually went back, leaving more and more of the bottom of the bay exposed, and the river had, of course, now to flow through a longer channel in order to reach the sea. As the waters retired they left a large part of the upper end of the bay, where the river had emptied itself at first, uncovered; and here the river had left its alluvium or sediment, spread out in a triangular form, or like the Greek letter Δ, the point representing the mouth of the river, and the broad part or base, the spreading out of the sediment, at first under the waters.

At this time nearly all the soil contained within this triangular piece, or Delta, was "mineral soil;" and was obtained by the river, from the "waste" of the hills and rocks. The sea appeared to retire, leaving the bottom of the valley, for such it now became, covered with the mineral soil brought down by the river. At first this soil presented the appearance of dried mud; and we should have looked in vain for the soft brown layer which now covers the whole valley from one end to the other. This brown layer consists of vegetable soil, and the vegetable soil had not then been formed, for the waters had only recently departed, leaving the ground dry.

The seeds of plants carried by the wind, or dropped by birds, fell upon the alluvium; soon they put forth roots and leaves, and flourished in luxuriance, for this soil is rich in those mineral ingredients which plants require for their nutrition. More and more vegetation took hold of the once bare surface, and it soon looked green and flourishing. Mosses, lichens,

and ferns, grasses and other herbs crowded upon it; and where but a short time previously the turbid waters of the river rolled, now in green glory wave a number of lowly plants whose vigour of growth attest the quality of the soil. So passed spring, summer, and autumn. But winter came and slew them, for they fell withered and dead beneath his icy breath, and showers of leaves, from the forests on the hills hard by, covered them as in a tomb. Then came the touch of Chemistry, with its magic wand. Air and moisture caused these stems and leaves to decay, and at length to become changed into that very mould which we now discover upon the surface soil.

The layer thus formed was of necessity very thin at first. But year after year added to its thickness. Fresh plants flourished and decayed, and so, in course of time, a considerable layer was formed, several inches in depth, mainly consisting of the residues from the decay of successive generations of plants.

Such is briefly the history of the vegetable soil of this valley.

In examining the chemical history of this substance, it may be profitable to select an anecdote of forest life, in regions where sun, air, and rain, together with other co-operating causes, act more powerfully than in our temperate climate.

The inhabitants of the vast primeval forests of the New World are frequently startled by the crash of falling timber, shaking even the solid ground under foot. On investigating the cause of the noise it is found to have arisen from the downfall of some vast vegetable monarch, which, after centuries of increasing

strength and grandeur, has at length fallen a victim to the exhaustive influences of time and decay, and lies on a heap of humbler forest trees, which it has dashed to the ground in its descent.

> "In the grove, at intervals,
> With sudden roar the aged pine-tree falls,—
> One crash, the death-hymn of the perfect tree,
> Declares the close of its green century.
> Low lies the plant to whose creation went
> Sweet influence from every element;
> Whose living towers the years conspired to build,
> Whose giddy top the morning loved to gild."

No sooner has the tree fallen than a number of agents set to work to effect its complete destruction. The rain-drops from heaven saturate it, the burning solar ray darts down upon and heats it, and favoured by the temperature and moisture, the air begins to act chemically upon the prostrate trunk. Insects come, and bore long galleries through its sides; ants and beetles also drill their holes through and through, and others eat away its bark. Thus rain and air get access to the very heart of the tree. By-and-by, the insects have taken their departure. The sun, wind, and rain have been, nevertheless, incessantly acting upon it; and now a tribe of painted fungi, of the most curious forms and splendid colours, grow upon the crumbling mass. Another portion of time glides away. Where is the prostrate tree?

The smiling sward, the up-springing flower, the unruffled aspect of surrounding vegetation, answer, "Not here—not here." Even so. The place which for centuries it covered with the grateful shadow of

its broad branches, which it protected from the fierce pelting of the tropical storm, and fiercer rays of a tropical sun, has forgotten even its existence. "The place thereof knows it no more."

Is it so? Is the tree not there? Surely it is; but its elements have all long since passed into another form, and some may at this moment actually form a portion of the vegetation which, by its thick and clustering growth, conceals the place where fell the forest monarch. The tree has crumbled into dust; and the dust has blended with the earth, and can no longer be distinguished therefrom. How has this great change been effected? By what means has the hard and unyielding woody fibre of this giant tree been broken up, and left a mass of powder? Chemistry gives the reply, and informs us, that it is by successive chemical decompositions that the loftiest inhabitant of the woods has fallen, and entered the common home of all living things, where the great and the small, even among plants, rest together.

When woody fibre is moistened, and freely exposed to the action of the atmosphere, it immediately begins to undergo chemical decomposition. There is an interchange of ingredients between it and the air. There is also a certain amount of heat evolved. The fibre alters its external characters, changes colour, and loses tenacity: in common language, it is said to be "rotting." The process goes on, the colour deepens, until at length it becomes brown, and the mass is so friable as to crumble to pieces in the hand.

The Chemistry of this change is not easy.

The process of decay in woody tissue varies much according as it is allowed to take place with free access of air, or is effected under water with but a scant supply of oxygen from without. When the atmosphere has free access, the oxygen of the air unites with some of the carbon of the tree and escapes as carbonic acid. Some of the hydrogen of the wood combines with the oxygen of the wood to form water. A small portion of the nitrogen is absorbed during the process, and ammonia is generated. As, then, the water is produced at the expense of the hydrogen and oxygen contained in the woody tissue, the mouldered product, or "humus" contains a proportionately larger amount of carbon than the wood itself.

The decay occurs most rapidly in young, spongy wood, which admits the air most freely, and at the same time contains a proportionately larger quantity of albuminous substance than the harder and older portions. The decomposition of this albuminous compound (albumen is known best as white of egg, but it is a substance widely diffused throughout the animal and vegetable kingdoms; it consists of carbon, hydrogen, nitrogen, oxygen, sulphur, phosphorus and sodium, and, from its very intricacy of composition, is most liable to undergo change) favours the growth of lichens and fungi, and encourages the ravages of insects, the death of which increases the manurial value of vegetable mould.

Sometimes, when the air-supply is limited and the vegetable matter is damp, as in the case of a haystack, the chemical changes occur so rapidly as to set it on fire. Heaps of tow, hemp, and cotton, especially

when oily, are thus capable of spontaneous combustion.

The most familiar example we could select of decay is the rotting of straw: in this case the decomposition goes on at so rapid a rate that the temperature rises very considerably. The heat of the manure-heap is turned to good account by horticulturists in the formation of hot-beds. The long and glittering stems of the straw break up, lose their golden lustre, and are gradually reduced to an earthy, brown mould.

Thus is vegetable mould produced. When decay has proceeded to a certain length, the constituents have become so entirely altered and re-constructed that further decomposition takes place but slowly. The mould or humus retains ammonia most obstinately, and furnishes nutriment to growing vegetables.

By the decay of herbaceous and aquatic plants in marshy soils, a material somewhat similar to humus is formed which accumulates in beds often of great depth and extent, constituting peat bogs. Dried peat contains more carbon than woody fibre; it likewise contains an excess of hydrogen over the oxygen.

While such is the process of decay adapted to the production of the vegetable soil, there is a remarkable variety which has a most momentous bearing upon the welfare of mankind. This is the decay preceding the formation of coal. In coal we see the remains of a vegetation which covered the earth before it was inhabited by man. Our coal-mines furnish almost a complete fossil flora, a history of many of the now lost species which once decorated the surface of the earth. Every bed of coal rests upon a bed of

clay, hardened into "shale," which is penetrated by perpendicular roots of plants. This "under-clay," as it is called, is therefore the old soil in which the coal-plants grew. Again, there generally rests upon the seam of coal, a bed of sand, or of shale, which is called the roof of the coal, and in which we find numberless stems and branches of different kinds of plants. Lastly, it is not unusual to find in the coal itself the trunks of trees still standing upright!

In the coal we find the remains of four principal types of vegetation. The most numerous are the ferns, some small and herbaceous resembling our own, others only comparable to the "tree-ferns" of New Zealand. Again, gigantic club-mosses attaining to the size of our trees, and known as Lepidodendra and Sigillariæ, are met with. Other plants, called Calamites, sometimes 20 feet in height, may be regarded as the prototypes of our tiny Equisetum, or "horse-tails." And lastly, we must mention a considerable number of trees, related to our yews and pines.

The more, or less, crushed and compressed remains of these plants constitute then our coal. Countless generations of plants must have lived and died, before the dark and rich vegetable mould could have accumulated to a thickness sufficient to account for the production of even one foot of coal. In a single coal-field we may find fifty or more beds lying one above the other. At each period a vegetation as luxuriant as its predecessor flourished and was buried, and so gave rise to other beds of coal.

The light and heat of our fires are verily the bottled-up sunshine of past ages. Through what ages we

know not, but to us they are countless. It has been computed that one-half a ton of carbon is produced in one year, on an acre of ground, in the most luxurious tropical vegetation. So that the amount produced in a hundred years, calculated as coal, would form a layer half-an-inch in thickness. When we think of seams of coal a yard in thickness, and even ten yards, we may well be lost in amazement at the antiquity of the earth, when it was, as "at the beginning," "without form and void."

And how favourably-placed is this England of ours as to its coal-beds. "What," says the late lamented Professor Fownes, "can be more striking than the aspect of an English coal-field, where iron-ore of excellent kind lies interstratified with the fuel necessary to reduce it? Where the lime-stone used as a flux, and even the very grit and fire-clay to build the furnace, are all to be found in one and the same series, often within a few yards of each other?"

But to return once more to the soil. When its chief constituents are inorganic, we may have argillaceous, calcareous, marly, or sandy soils, according as clay (silicate of alumina), chalk (carbonate of lime), or sand (silica) predominate. But these are mainly the holdfasts for the plant. Other mineral matters are necessary, and these are those which would be met with in vegetable mould, or in the ash of plants. We all know that when we burn wood an ash remains; it was this wood-ash material which assisted in the production of the wood, and if this be returned to the soil, the necessary mineral matter is at once to hand for the further luxuriant growth of leaf and

stem. Plants of different species require different proportions of soluble mineral matters. Thus root-crops require much potash and soda; all require more or less of soluble phosphates, especially seeds, and their nutritious properties are generally in proportion to the amount of exhaustion which they occasion in the soil.

CHAPTER IV.

CHEMISTRY OF THE INTERIOR.

We have seen that on the surface the powers of nature are never at rest; that the repose which prevails is apparent, not real, and that there is a ceaseless law of change influencing all the objects which have been presented to our notice. All seems working in one direction, attacking the land, and sweeping away portions of its surface. Are we to imagine that the earth's Chemistry is only applicable to the surface, and that all within is quiescent? Could a sudden rent be made through the earth's crust and we look down into the gulf below, we should doubtless find that there was no scene of quiet, no sign of repose. It may be thought there is little for the student of nature to investigate here, because of the want of such power on his part to make the necessary rift. But we shall proceed to show that in various ways a great variety of interesting information is afforded to us, as to the chemical processes in operation, in regions to which no mortal eye can penetrate.

True, the fairy tales of the East represent the world below as a scene of enchanting beauty, a palace adorned with bright, glittering jewels, and with minerals of wondrous structure and of dazzling lustre. If

so, such beauties are unknown to us. All the idea we are able to form of its contents must be drawn from the emitted products with which we are familiar; and these, singular as some of them are, do not justify the conceptions that might be formed of any romantic regions of beauty below the earth's surface. The interior is constantly reacting upon its exterior, as we have evidence in the earthquake and the volcano, and by the magnitude and extent of these phenomena we may form a conception of the force of the powers within.

Let us then examine some of those natural phenomena which seem to help us to some sort of acquaintance with the Chemistry of the interior. And we may first allude to the remarkable facts which have been discovered, relative to the temperature of the earth's crust.

If a thermometer is taken with us as we descend into a mine and carefully examined, it will indicate a gradual rise of temperature proportionate to the depth of the descent. The actual increase has been ascertained by a number of experiments made in different countries, and amounts to about one degree (1°) of Fahrenheit's scale, for each 55 feet in depth. A thermometer placed in a hole cut in the solid rock at a depth of 1,380 feet, was observed to register 68° F., while, at the same time, the temperature at the earth's surface was only 50° F. It is a familiar fact also, that the miners working at great depths in the earth enjoy a kind of perpetual summer, which is almost entirely unaffected by the condition of the surface, even though the earth be clad in the cold

and glittering raiment of the sharpest winter. There is a mine in Cornwall, one of the levels of which is so hot, that although a stream of cold water is purposely allowed to flow through it in order to reduce the temperature, the miners are compelled to work nearly naked, and will bathe in water at 80° F. to cool themselves. In another mine in the same county, which has been carried to the depth of 320 fathoms, the temperature is hotter than on the surface on the warmest summer day in the shade. The Artesian wells illustrate the same fact. These wells are formed by boring to the depth of many hundred feet in the earth. The celebrated Artesian well at Grenelle, near Paris, is sunk to a depth of 1,800 feet; the temperature of this pure and abundant spring is 82° F. It is supplied by the rains which fall on the permeable strata of Champagne, 100 miles distant from Paris. London is very similarly situated geologically. The Artesian well in Trafalgar-square penetrates the chalk to a depth of nearly 400 feet beneath the surface, the water-supply coming from the rain which falls upon the chalk hills twenty miles off.

The phenomena of hot springs, volcanic eruptions and earthquakes, all seem to indicate a high temperature in the interior of the earth. Now, if the same increase of temperature continued as we descended, supposing we could bore to the depth of rather less than two miles, water would rise up through the tube at the boiling-point, or 212° F.

If, as seems most likely, the earth existed at one time in a state of fusion, much of the great internal

heat is simply residual. But this would not altogether account for the source of heat. There must be both mechanical and chemical causes.

Undoubtedly the heat of the interior is no longer due to the sun's rays, whatever may have been the case in bygone ages. A few inches below the surface of the earth the alternations of heat and cold are perceptible even to the hand. But only a few feet down, and the temperature is uniform, and uninfluenced by summer's suns and winter's frosts.

With some slight sources of internal heat we are acquainted. Thus the mineral called iron-pyrites, which is a bi-sulphide of iron, on exposure to moisture may oxydize and give rise to considerable increase of temperature. Immense masses of this ore are found in the earth. M. F. Leblanc examined the air of the galleries of a mine of iron-pyrites in a district in Brittany, and found that it contained but 17 to 18 per cent. of oxygen (instead of the usual 21 per cent.), and in some parts only 10 per cent. This effect is attributable to the pyrites-wall of the mine-absorbing oxygen, and this process cannot go on without the evolution of much heat.

We must then dismiss the question as to the cause of the great heat of the interior of the earth. Amongst the effects we may notice that great heat occasions the decomposition, or dissociation, of compounds. When the temperature of water is greatly increased, it is separated into its elements, oxygen and hydrogen. Hence it is possible to conceive of the elements intermingling one with another at one depth in the interior, without any tendency to unite; at another,

nearer to the surface, uniting to form compounds with the usual display of exalted temperature.

That tremendous natural phenomenon, the earthquake, may be mentioned as giving countenance to the idea that the interior of the earth resembles a great chemical laboratory. Let us now advert to some particulars concerning it, and in so doing, briefly mention the external phenomena which accompany these appalling catastrophes. A violent explosion is often heard, such as is produced by the firing of a mine, although the occurrence of this is uncertain; then follow a series of concussions and vibrations, the bosom of the earth heaves up like a sleep-disturbed giant, thunderings like legions of artillery roll beneath the feet, and deep chasms open up, ejecting torrents of mud, or sulphurous winds. Clouds of black smoke, fountains of boiling liquids, gusts of deadly gases, jets of steam and up-springing flames form its dreadful accompaniments, and spread desolation and anguish around, while overwhelmed, or suffocated, men and animals fill the air with their cries. Shoals of fish are cast upon the uneasy shore, while reptiles and vermin die choked by the streams of carbonic acid and other gases which issue from the earth.

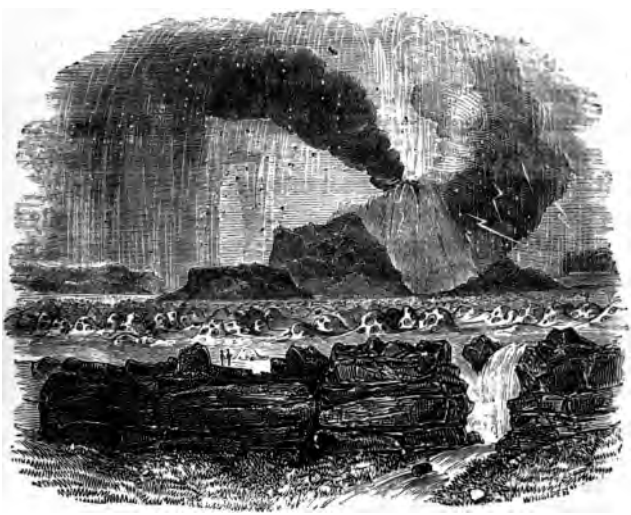
Much attention has been given to the study of earthquakes by Mr. R. Mallett. He has come to the conclusion that the origin of the disturbance never exceeds a depth of thirty miles in the interior of the earth. Shocks are not at all of rare occurrence. If the disturbance takes place near to the sea, the water is more affected than the land, and the waves are often

fearfully destructive, as was the case on the coasts of South America in May, 1877.

Another evidence of subterranean movement is the volcano. Every stage of volcanic violence is attended with peculiar chemical phenomena. At first, when the vast artillery of Nature opens fire, glowing ashes shoot up into the heavens, then a molten flood of lava is pressed up into the crater, and rolls down in devastating terrors upon the smiling country below. At a later period, steam, sulphuretted hydrogen and carbonic acid gases are the only symptoms of chemical activity; and lastly, when the fire is almost extinct, carbonic acid gas alone rises from the once fire-glowing crater. Vapours of hydrochloric and sulphurous acids, together with pure nitrogen gas and ammonia, have also been detected among the gaseous exhalations of these fountains of fire. The celebrated volcano of Jorullo rises out of a plain, the remarkable aspect of which communicates a vivid idea of the activity of chemical forces going on beneath the surface. This scene is represented in the accompanying engraving. The molten rock which overflows from the volcano is called lava. There can be little question that the eruption acts like the opening of a safety-valve, and relieves the accumulating pressure of contending elements within, which, if the volcano-vent were closed, would result in the production of dreadful earthquakes, more destructive and desolating than any volcanic eruption.

In addition to these violent indications of chemical activity, we are presented with some which are not less interesting in their nature, although less tumul-

tuous in operation. One of the most common is the effusion of carbonic acid gas, in very large quantities, from cracks and fissures in the ground. In many volcanic districts this phenomenon exists in a remarkable degree. Frequently also it rises, largely dissolved by the waters of springs in such localities.



VOLCANO OF JORULLO.

The gas being invisible, and, excepting when undiluted, destitute of odour, its presence is not so easily detected as that of some other gases. When volcanic fires are dying out, large emissions of it take place. As soon as Vesuvius has ceased to emit lava, there escape immense volumes of carbonic acid from

the crater, and these, entering the atmosphere, are well known by the Italian people under the title of the Moffettes. These streams of gas are sometimes dangerous to life, if a person is exposed to their full influence. So largely does carbonic acid escape from the ground in the far famed Grotto del Cane, near Naples, as to cause it to be fatal to animals which, whether by accident or design, are exposed sufficiently long to its effects. All the dogs for miles around dread the spot, for it is a common experiment to put them into the cave until they are insensible, and then to bring them to life again by throwing them into a pool of water!

The celebrated Upas valleys owe their deadly repute to a similar cause. These valleys are described as about half a mile in circumference, full of the skeletons of men and animals, and teeming with the sources of carbonic acid gas. They are narrow, flat, and desolate,—very valleys of the shadow of death. Universal death holds sway! Heaps of dead insects and birds lie around,—sad proofs of the character of the gas. The fatal air rises to the height of about 18 feet from the ground. The only plant which flourishes there is the tall and fearfully poisonous Pohon upas-tree, which grows luxuriantly amid a scene of the gloomiest description. This gas is in other districts so abundantly evolved from the earth as to be heard issuing with a hissing noise from cracks in the limestone: and it often proves fatal to birds which unconsciously come within its influence.

Carbonic acid appears, however, under circumstances where volcanic agency plays no part. Evolu-

tion of this gas takes place in the vicinity of extensive layers of wood-coal, principally, however, in the form of an aqueous solution; in other words, as carbonated springs. The gas may often be seen bubbling around the edges; and the pleasant waters of some of these springs make them a valuable possession to the inhabitants.

From these considerations we learn, that the escape of this gas is an indication of two classes of chemical activities—first, of volcanic decompositions; and, secondly, of those more gradual changes, which time produces in the constituents of the coal-layers or measures. Both these decompositions possess interest. It appears more than probable that the true source of this gas, in the first case, in volcanic districts, is that simple decomposition which heat effects in limestone, whereby a portion of its carbonic acid is discharged,—a decomposition precisely similar to that we effect in burning limestone, the gas of which has so often proved fatal to the incautious traveller. The intense heat of an eruption must affect all adjoining rocks; and it is presumed that the calcareous, or limestone rocks, heated by this means, lose their carbonic acid, and produce the phenomenon in question. We have the authority of Dr. Daubeny for this supposition. There is less difficulty in discovering the source and mode of production of the gas in the latter case. In the chemical decompositions which accompany the formation of brown coal, carbonic acid is extracted from the substance of the wood. (The same gas is also produced by the combustion of the fire-damp of coal mines, and consti-

tutes the deadly exhalation called "choke-damp" or "after-damp" by the miners.) Water percolating through the soil to these strata, and meeting with the gas, dissolves it, and rises to the surface as an acidulous, effervescent, or carbonated spring.

But, from whatsoever source proceeding, this gas—itself in all cases an undoubted evidence of chemical decomposition at a depth below the surface—is the cause of important chemical changes in the crust of the earth. Feeble as the agency may appear, the gas being a weak acid, exerts in reality a most powerful decomposing and disintegrating effect upon the different strata through which it is compelled to pass in its passage to the surface. Strata, which would otherwise remain solid and intact for centuries, are ready to crumble to pieces in consequence. Dissolving, by its solution in water, many of the constituents of the rocks, it eventually makes them into a soft pulp, or even, as in the case of limestone rocks, it may produce those great caverns and long galleries, of which different countries present us with such curious and magnificent specimens.

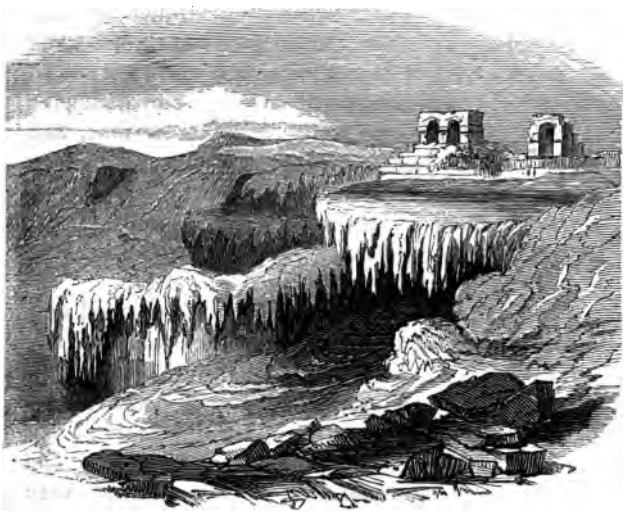
At Friedrichshall, in Norway, is a cavern 11,000 feet deep. The most celebrated caverns are those of Adelsberg in Carinthia, on the road from Vienna to Trieste, and the so-called Mammoth Cave of Kentucky in America. The mere vestibule of the Austrian cavern, called the Dome, is upwards of 100 feet high, and more than 300 feet deep. The floors are often nearly level and hard, consisting of sheets of limestone which have been deposited from the water. Within there are often sheets, columns and pinnacles

of stone, which, when undimmed by the smoke of lamps and torches, are half transparent, and of the most brilliant yellowish-white appearance. These hang down from the roof, rise up from the floor, arrange themselves fantastically as curtains, tables, or festoons, and even assume the appearance of men and animals. All of them have been formed by the drip of water. While penetrating through innumerable small cavities in the limestone rock, the water takes up a part of the mineral and carries it along, eating away its course, partly chemically by dissolving the carbonate of lime as bi-carbonate of lime, and partly mechanically by constant rubbing.

When a solution of bi-carbonate of lime loses part, or the whole of its carbonic acid gas, the calcareous matter (carbonate of lime) is deposited in the form of a white, solid, dense mass called "travertin."

A remarkable example of water fully charged with carbonic acid, and holding a large quantity of calcareous matter thus obtained, occurs in a lake existing in the Campagna of Rome, called the *Lacus Albula*, or the Lake of the Solfatara. The water is so impregnated as to assume a bluish milky aspect. The ancient Romans erected their baths here, which were celebrated for the cure of disorders of the skin. The temperature of the water is about twenty degrees higher than the average, or mean temperature, of the air. "Reeds, lichens, confervæ, and a vast mass of aquatic vegetation," says Sir H. Davy, "here find a rich repast, and grow in the utmost luxuriance, forming a number of floating islands on its surface." In certain districts of Asia Minor, the springs are so

charged with calcareous matter as to deposit it in extraordinary quantities. It is said by a traveller into those regions, that, in order to make some stone fences round the gardens and vineyards of Hierapolis, it was only necessary to conduct the water of such springs into narrow channels, and they soon became



PETRIFYING SPRINGS.

filled up with stone! Even high roads are thus easily laid down by other than human skill. When such springs run over an eminence, they present the curious appearance of a frozen cascade.

An equally singular exhalation, also indicative of decompositions deep in the earth, is that of light

carburetted hydrogen, or "coal-gas," called by miners the "fire-damp." Being invisible, like carbonic acid, it is only to be detected by its peculiar odour, and its inflammability. When once a light is applied to these streams of gas, they instantly inflame, and often continue burning for years, until the supply ceases. In the village of Fredonia, in the State of New York, gas thus naturally produced has been collected and used to light the streets with, and also for heating and cooking. At the edge of the river above the rapids, at the Falls of Niagara, a burning spring exists. The gas makes its way in countless bubbles through the clear transparent waters of the Niagara. On the application of a candle it takes fire, and plays about with a lambent flickering flame, which hovers around at some distance from the surface of the water. This gas rises out of a bed of limestone rock, probably from the decomposition of some bituminous matter below it. The Chinese collect it in such quantities, by means of bamboo tubes, from wells, where it is produced naturally, as to apply it on the large scale for heating evaporating pans. One such well is said to heat more than 300 pans. The production of the gas in this, as in some other instances, appears connected with saline springs. It is related that, while boring for salt near Lake Erie, the borer suddenly fell, after penetrating to the depth of 197 feet. Salt water sprang up for several hours; after which, a considerable quantity of inflammable gas burst forth from the same aperture, and, being ignited by a fire in the vicinity, consumed all within its reach. A similar eruption of this gas was related to the writer,

as having occurred in a magnificent salt-mine near Northwich, in Cheshire. On a hole being made into the floor of the mine, suddenly up burst a jet of gas, which caught fire, and streamed 14 feet high, until it was put out by the terrified miners. The hollow sound of the floor of the mine had led them to suspect some cavity beneath; and on their boring into it, the escape of gas was the unlooked-for result.

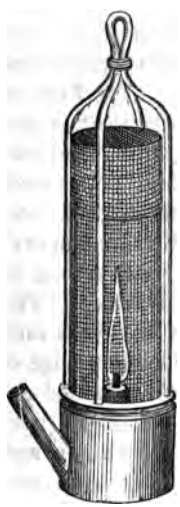
In many of the coal-districts of the north, this gas is frequently found issuing in jets from the ground; and it is almost surprising that a product of so much value should be allowed to discharge itself and become lost in the atmosphere.

At a meeting of the British Association at Birmingham, an interesting account of a continued spontaneous evolution of gas from the ground was communicated, which may be transferred to these pages. "In a field by the side of a lane near the village of Charlemont, in Staffordshire, certain patches of ground had been noticed, which, without any apparent cause, were destitute of vegetation. The person who first paid attention to the cause of these barren spots was the tenant of a neighbouring cottage, at which there is a cold bath, noted in the vicinity for its sanative properties. From certain circumstances he was led to believe that something permeated the earth in these spots, and having dug a hole he inserted a gas-pipe, and on applying a light to the mouth of the pipe, he found, to his great delight, that a large flame issued from it. It was not long before he conceived the idea of applying it to domestic

purposes, and, in pursuing his experiments, he found that it was not necessary to convey it from the place where it was first discovered, at a distance of about 150 yards from his house, as in driving a pipe some inches into the ground, under the floor of his cottage, he procured a continuous flow of the gas. There are, at the present time, seven burners in the cottage, which enable the owners to dispense with fire and candles. The next cottage is also supplied with two. It appears to make no difference to the supply of gas if allowed to burn for weeks together. The flame is always of the same colour. In windy weather the flame is unsteady: when there is a blast of wind outside, the flames of gas rise several inches, but as each blast dies away, they return to their original size. The escape of gas is larger in wet weather than in dry; but whether the gas is produced near the surface or not, has not yet been satisfactorily ascertained. The place where it issues from the earth is quite a mile from any coal-pit, and is outside the eastern edge of the Staffordshire basin. Upon analysis it turned out that the gas was chiefly composed of marsh-gas (light carbonetted hydrogen, a compound of carbon and hydrogen) mixed with a little carbonic acid and nitrogen. It burns with a pale bluish-white flame, emitting considerable light and heat. As it issues from the pipe it has a moist or slightly musty smell, as of sticks partially decomposed; but after it has been kept a little time, it becomes quite inodorous. It does not appear that the employment of it entails any evil consequences on the health of the family." When it escapes into mines, it constitutes the

dangerous gas too well-known as "fire-damp." This gas becomes explosive only when mixed with a certain quantity of air; if then a flame is applied to the mixture, it explodes with all the violence of gunpowder, and with great noise.

In consequence of the awful accidents which have occurred, owing to the escape of this gas into coal-mines, and to its subsequent explosion by coming in contact with the lighted candle of the miner, Sir H. Davy undertook the task of endeavouring to discover some remedy for these calamities. His labours were ultimately rewarded by the discovery of the invaluable *safety-lamp*, with which his name will be connected through all time. It may be interesting to state the principles upon which the success of this simple and beautiful invention depends. The lamp is, in reality, only a common oil-lamp, surrounded by a wire gauze. It may be trimmed by a small bent wire which projects from the bottom of the lamp. So completely is it shut in, that the supply of air for its combustion can nowhere come to it but through the wire gauze. Now, when this lamp is put into an atmosphere consisting of fire-damp and air, it does not cause it to kindle and explode, as a common candle would do; but, strange to say, the light of the wick goes out, and the interior of the gauze cylinder



THE SAFETY-LAMP.

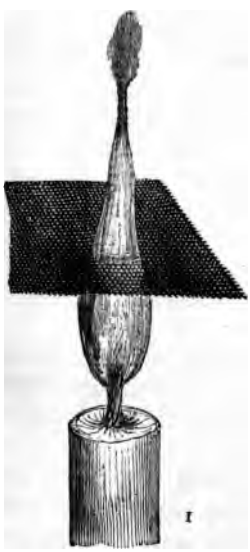
becomes filled with a pale blue lambent flame, caused by the fire-damp and air taking fire within it, and burning without violence. On being taken out of such a mixture, the wick again catches fire, and the blue flame disappears. Whenever this pale enlarged flame is seen, the miner must withdraw; for though no explosion can occur while the gauze is sound, yet at that high temperature the metal becomes rapidly oxydized, and might easily break into holes, when the mixture of fire-damp and air outside the lamp would become ignited, and immediately cause an explosion.

A mixture of one measure of fire-damp and ten measures of air, when inflamed, produces the greatest detonation: if the miner is not killed by the shock and the sheet of flame, he may die from inhaling an atmosphere consisting mainly of carbonic acid, nitrogen (from the air), and watery vapour.

It is therefore the wire-gauze alone which protects the miner. That which is used in the construction of these lamps contains about 750 meshes to the square inch.

The explanation of its action is as follows:—The explosive mixture will not take fire unless the ignited body applied to it is at a bright red heat. The flame of the wick would therefore cause it to ignite and explode immediately; but before this flame could pass to the fire-damp, so as to communicate sufficient heat to kindle it, it must transfer the same amount of motion, as itself possesses, to the heavy gauze. The consequence is, the heat is so much lowered, that combustion cannot be communicated to the opposite side of the gauze.

If the reader will take a piece of wire gauze, and hold it over the flame of a candle, he will find that for a little time the flame will not pass through, and that he can, in fact, look down into the centre of the flame (fig. 2), which is hollow. After a time, however,



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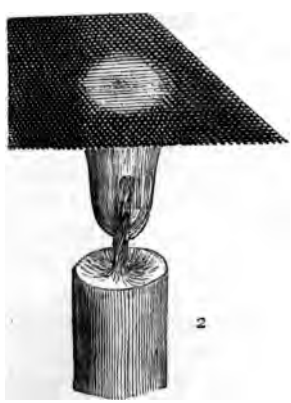


2

the wire becomes so heated that the flame does pass, and then presents somewhat the appearance at fig. 1 in the cut.

In a strong current of air, the heated gas may be blown through the apertures of the gauze, before its temperature is sufficiently reduced to prevent the explosion. And the circumstances under which coal-

mining is at present performed, the greater depths, the varying pressure, the incomplete ventilation, &c., &c., have introduced elements of danger almost unknown in the days of Davy. So many lives have been sacrificed, that a Royal Commission was appointed in 1879 to inquire into the causes of accidents in coal-mines.

Much of the fire-damp is stored, in cavities of the coal, in a liquid form. If unable to discharge itself, a blow of the miner's pickaxe may strike the place, and the gas issue forth in quantity. Such a stream of gas is called a "blower" by the miners.

The formation of the gas is very intelligible and very similar in character to that which is produced in the distillation of coal.

We can also give a satisfactory account of another natural phenomenon, the springs of rock-oil, petroleum or naphtha, which are found in some districts. We know that when pit coal is distilled, a certain quantity of an oily liquid is obtained, which resembles in many respects the mineral oil obtained from these springs. Hence it is reasonably concluded that the production of this fluid is due, when it occurs in nature, to the action of heat upon vegetable matter under the surface, in, or near, the coal formation, causing the petroleum to be formed, and then distilled, by a very slow process, into the layers of earth overlying them, where this substance is generally found.

In a coal-pit near Alfreton in Derbyshire, a spring was discovered many years since, yielding from 150 to 30 gallons a day. The oil as it issues is of a dark tarry colour; but, on being distilled, yields, among

other products, a colourless oil which forms a very valuable source of light when used in a proper lamp. This liquid is called benzene, and it was first discovered by Faraday: it occurs in large quantity in the naphtha obtained by distilling coal, and is now used in the preparation of anilin and in the manufacture of beautiful dyes.

In American petroleum and in the mineral oils of like nature, we have an admixture of hydrocarbons belonging to the group of paraffins. Some of them are solid, like ozokerit, mineral wax, &c., and are largely employed in the manufacture of candles. Some are semi-solid, and are used for lubricating machinery. Yet others are liquid. The petroleum used for burning in lamps must not contain any liquids volatile below 100° F. Petroleum spirit, the most volatile portion, has to be removed by distillation below 100° F., and is much prized as a solvent of india-rubber and such-like bodies.

The highly-remarkable phenomena of mud volcanoes, that is, of volcanoes which pour down enormous streams of mud, frequently without giving the least intimation beforehand, are probably also of chemical origin. Hot water issuing from the ground, is mixed with earthy matter, and streams of thick mud accumulate round the openings. The eruption of the mud volcano of Galungung, in 1822, was among the most fatal catastrophes of this kind. Without warning, an immense volume of mud filled the crater, and streamed down in a great torrent upon the valleys and plains beneath. In its course it filled up the river courses, covered over hollows

from 40 to 50 feet deep, and turned a fertile area of land, 40 miles square, into a desert. This extraordinary eruption destroyed hundreds of thousands of coffee-trees, many acres of rice-fields and besides a vast number of inferior animals, overwhelmed not fewer than from ten to eleven thousand human beings.

AIR VOLCANOES.

In certain parts of South America are volcanoes which only emit water and gas. They are called air-volcanoes. In all probability the "air" consists chiefly of carbonic acid and nitrogen. (The cut represents some of these.)

In further illustration of the subject of this chapter,

an instance of a highly interesting nature may be selected, which gives us a most lively picture of the importance to man of several of the chemical phenomena occurring in regions to which he has no possibility of access. The substance called Boracic Acid is such a product, and its most important and singular source is in what are called the Maremma of Tuscany.

The scene where these lagoons are situated is one of peculiar wildness. Conceive a region in the heart of bleak and solitary mountains, where the earth seems to be pouring out boiling water; where clouds of hot vapour come bursting from its surface, drenching the visitor to the skin, and impregnating the whole surrounding atmosphere with the strong smell of rotten egg gas! The heat is intolerable. The rugged surface of the ground seems ready at every moment to break up and disclose some awful pit beneath, whence the boiling springs and clouds of steam arise. The ground trembles and shakes beneath the feet, and loud concussions are both heard and felt without cessation. No wonder that the peasantry are alarmed and regard the spot as the very mouth of hell! The surface of the earth is covered with beautiful crystals of sulphur, resulting from the slow action of the escaping sulphurous acid and sulphuretted hydrogen.

The "lagoons" consist of rude circular basins, partly excavated, partly built, which are situated exactly over some of the fissures in the ground, from which the bursts of vapour rise. These basins are ranged one above the other, so that the overflow from the highest runs in succession down to the lowest; and they are filled with water arising from a rivulet

which runs into the uppermost of them. The hot vapours rising by their natural conduits from that disturbed region below, where the chemical combination producing them takes place, bring with them the boracic acid, which, on entering the water of the lagoons, becomes condensed and dissolved by it. After the acid liquid has passed through all the basins, it is evaporated in an ingenious manner by pans, which are heated by the vapours arising from the earth. It is then crystallized, dried, and sent to the market. About two thousand tons of the crude acid are thus procured annually in Tuscany. The crude acid, however, seldom contains more than three-fourths of its weight of the pure crystallized acid. The substance called "borax" is made from boracic acid and carbonate of soda. But it is also found native. A part of what is used in commerce is obtained from the waters of certain lakes in Thibet and Persia; it is also imported from India under the name of "tincal." Borax is largely employed in glazing earthenware, in soldering metals, and in the operations of fluxing and assaying.

Dr. Bowring has remarked that, probably, in the course of time, this vast machinery of heat and force will be turned to account in the promotion of other manufactures. Even now the peasantry watch the emission of vapours from the lagoons, and judge correctly of the weather. If there is much vapour, it betokens wet; if less than usual, it foretells fine weather. We may believe these indications to be connected with the atmospheric pressure: when it is small, the escape of vapour is rendered easier, and

more difficult when the pressure is increased. The increase or diminution in the amount of the united vapours forms thus, in reality, a barometer that serves to indicate the weight of the air. Such is also the case in regard to our coal mines, in which fire-damp escapes abundantly when a sudden fall of the barometer takes place.

At all periods the earth's crust has been incessantly under the influence of chemical force, and, consequently, the character of its constituents has been constantly undergoing remarkable changes. The peculiar process, called by geologists the metamorphism of rocks, is a striking illustration of this. In various parts of the earth's crust there is evidence of a heated mass of rock having been pushed up from below completely through the overlying beds. Such rocks are called Eruptive. Their temperature at the time when they broke through the overlying, or sedimentary beds, must have been very great; certainly not less than 1,000° Fahrenheit. The result of the application of this intense heat to the sedimentary strata has been in many cases to produce the most remarkable alterations in their chemical composition, or in the arrangement of their particles. Thus, rocks have been metamorphosed into substances very different from their original constitution. The celebrated Carrara marble, which, from its unsullied purity of composition, has for ages supplied the principal supply of marble to the sculptor and architect, appears to have undergone this peculiar change; and beds, representing the original limestone previous to its metamorphosis, have been discovered. It appears

to have been melted under high pressure and in absence of air, so as not to have lost its carbonic acid, and afterwards to have cooled down and crystallized. The common blue slate, used for roofing, is another instance of a substance altered by the same process. It is nothing more than clay or silicate of alumina, that has undergone a great amount of squeezing, and has become so completely altered as to assume a curious kind of half-crystalline appearance and condition presented by no other substance. We have only to observe the surface of the ground in slate districts, to satisfy ourselves that slate is nothing more than clay. But although it is easy to convert slate into clay, it is in many respects singularly unlike the latter; for it splits into thin films when struck in one direction. But few simple minerals are found in beds of clay. Heavy spar, or sulphate of baryta, occurs in crystalline form in the interstices of clay beds, while transparent crystals of selenite, or sulphate of lime, are tolerably plentiful in some of the beds. Whilst, then, clay is a rock in which little mineral wealth is found, slate, on the other hand, especially when near granite, contains some of the richest and most valuable ores. The ruby and the sapphire consist of alumina: the emerald is a compound of silicate of alumina and glucina. The beryl is a mere modification of the emerald. Our common clays, as they are called, furnish, by the occasional introduction of small quantities of other substances, a variety of comparatively rare minerals, including all those common in volcanic districts, all volcanic ashes and minerals thrown out during eruptions, and those

also which are afterwards found in the clefts and cavities of the hardened masses.

We have said that slate; especially when near to the granite, contains valuable ores; by these we mean minerals which yield metals. Gold and platinum exist in the metallic state, and are generally obtained from sands and gravels. Silver is also frequently found native, but never like gold in sand and alluvial soil washed down by streams, but among primitive rocks and in veins traversing slate and similar deposits. Its chief ore is a compound of silver and sulphur. The metal tin is found as an oxide, and is known as tin-stone. Iron is also most abundant in an oxydized condition. England is especially rich in the earthy ores, such as the common clay-ironstone. Sweden, on the contrary, has large deposits of the oxide, valuable for making the best kinds of steel. Most of the great lead deposits consist of a combination of sulphur with the metal. Copper was obtained by the ancients from the island of Cyprus, whence the name Cuprum; it is sometimes found native, as copper, but more generally in combination with sulphur and iron as copper-pyrites. Mercury is also principally met with as sulphide, and is known as cinabar. Manganese is found as an oxide. Antimony and arsenic occur mainly as sulphides.

To the student of nature's Chemistry, few countries present an aspect so attractive as does the waste and desolate island of Iceland. The most important of the strata of rocks concerned in the chemical phenomena of Iceland is a rock called Palagonite. The constituents of this rock are chiefly hydrated silicates;

that is to say, combinations of silica with oxide of iron, alumina, lime, magnesia, potash, soda, and water. These ingredients, when exposed to the volcanic gases, sulphurous acid, carbonic acid, hydrochloric acid, and sulphuretted hydrogen, become acted upon in a variety of ways, and form, with the latter and each other, a variety of fresh combinations. The palagonite becomes converted into beds of ferruginous clay, interpenetrated by beds of gypsum or sulphate of lime. Around smoking orifices of the fumeroles, thick crystalline crusts of sulphur are deposited. The source of this sulphur appears to be the mutual decomposition of sulphurous acid and sulphuretted hydrogen, the result of which decomposition is the deposition of sulphur. Sulphuretted hydrogen is formed in small quantity wherever organic matter decays in the presence of gypsum (sulphate of lime), but in volcanic countries it frequently occurs in considerable quantities. From fissures and openings in the solfataras of Italy, for example, as at Pozzuoli, it rushes out mingled with watery vapour, and may be detected not only by its action on white lead or on salts of lead, but by its offensive smell. By the constant passage of the volcanic gases through the palagonite, a number of chemical phenomena are continually proceeding; and the changes thus produced are manifest on the surface in saline incrustations and mineral productions of various kinds.

Perhaps one of the most interesting features in the Chemistry of this wonderful country is the formation of its geysers. Professor Bunsen explains the whole

process in a beautifully clear and simple manner. In the mutual reaction of carbonic acid, sulphuretted hydrogen, and heated water, and the palagonite, are combined all the conditions required by nature to convert, in the course of centuries, simple boiling springs into geysers, whose clear, vapoury and foaming columns of water shall burst from the summits of their self-created craters, either continuously, or at periods of a few minutes, hours, or days. The explanation of this remarkable fact is as follows. The water of these boiling springs contains a dissolved hydrate of silica, which on its evaporation is deposited around the mouth of the spring, on the margin projecting beyond the level of the water. Of course, in the basin of the spring, and below its surface, no evaporation takes place, and therefore no incrustation can occur. Imagine, then, this process of incrustation around the edge of the spring to continue for years, the natural result would be, that the margin would become higher and higher, forming a rocky tube of silicious matter. As the margin rises, the water of course rises also, being always a little below the latter. The consequence is, that the spring, by this continued process of deposition, increases in height, until, reaching a certain altitude, it becomes converted into a regular geyser. Surrounding the tube formed in this simple manner, is a hillock of silicious matter, formed by the overflowing of the water of the spring. From the mountains above them these tubes are fed with water, which becomes heated in the volcanic subterranean channels along which it is conducted. This high temperature converts a part of it into vapour, and the

result is that the water, elevated by its expansive force, foaming and hissing, rises up through the tube which the incrusting waters have reared, and rushes boiling out of the mouth of the spring. Iceland abounds in these springs.

But the Great Geyser, as is well known, is an intermittent spring. Its phenomena are different from the smaller geysers or hot-springs. Instead of continually discharging a boiling stream of water, as the other springs, there are intervals of time between its eruptions. The cause of this has been generally explained to be the existence under ground of great cauldrons, in which steam accumulated until its elastic force drove up the water through the Geyser tube, after which it subsided again. But this explanation is incorrect: the mouth of the Great Geyser tube is so wide, that although the water at the bottom is heated, and partly converted into vapour, yet the loss of heat at the surface by evaporation and radiation is so great, that the whole volume of water in the tube is not brought up to the boiling-point excepting at stated times. When this is the case, then it appears that a powerful volume of vapour accumulates at the lower part of the tube, which, acquiring fresh elastic force, at length lifts the immense body of water above it into the air, driving it in a roaring, rushing column 28 feet in circumference, and 100 in altitude; after this the spring becomes quiet again, until its column is again heated up to the boiling-point. The phenomena of the intermittent Geysers have also been explained in a somewhat different way. The water in the lower part of the great tube, though hotter than

ordinary boiling water, is a little below the point at which it can boil at that depth, for its boiling-point is raised by the pressure of the column of water above. Some slight explosion below elevates the column, and a little of the water overflows. The pressure being thus reduced, a burst of steam occurs, and the whole column is hurled into the air.

As the incrustation continues, the sides of the tube rise higher and higher, until they and the surrounding ground attain a height which puts an end to these singular phenomena. As soon as the supply of heat from below and the cooling at the surface are so far in equilibrium that the temperature of the mass of water is not anywhere able to reach the boiling-point, the action of the spring ceases spontaneously. Large reservoirs filled with hot, stagnating, or running water are thus formed. Old Geysers abound in various districts, appearing in the form of large reservoirs filled with hot water, in the depths of which the old mouths may still be seen. These springs are extremely beautiful, and in one region of this wild country, in particular, their aspect is highly interesting. In the depths of the clear unruffled blue waters in this district, from which still rises a light vapour, the dark outlines of what once formed the mouth of a Geyser may be faintly traced amid the fantastic forms of the white stalactite walls of the basins.

The silicious deposit, the grand agent in producing all the splendid phenomena in question, is produced by the decomposition effected in the palagonite rock by hot water, carbonic acid, and other gases. Altogether, viewing the whole of the Geyser phenomena

in connection with the lapse of time necessary to the formation of one of these vaporous fountains, and contrasting the magnitude of the result with the apparent feebleness of the cause, we cannot fail to be struck with the view it presents to us of the grandeur, force, and beauty of the Chemistry of nature, in this wild and wonderful region.

A few words about silica may not be inappropriate. It is far more common than alumina: like the latter it is an oxydised or completely burnt body. Rock-crystal is a variety of silica. The Brazil pebble, the amethyst and cairngorm consist of silica. Then we have agates, carnelions, chalcedony, heliotrope and jasper, with many other representative specimens of silica. Sandstone and flint are made of silica. Even the precious opal is but a combination of silica and water!

Flints are curious from their origin. Under the microscope they always exhibit some fragment of sponge, or the shell of a small animal, or some other proof that they were not always what they are now. Not unfrequently they are broken, and we see a hollow space in the middle, sometimes partly occupied. Here and there is a flint, with part of a shell, or a portion of a sea-urchin, or sea-egg, sticking deeply into its substance. More frequently there is unmistakeable evidence of a sponge, round which the flint seems to have formed, and altogether the silica would appear to have been once in solution in water, and to have petrified the organic remains.

There is something deeply interesting in contemplating the small, as well as great, phenomena of

nature. The land itself is then subject to a rapid fall and rise, and to local elevations and depressions so gradual as to escape ordinary observation. And, indeed, the latter are the more important, although they are less easily observable, and special methods are required to measure their extent. Deposits which once formed the bottom of the sea now form our dry land. On our coasts we may remark a terrace of sand and gravel mixed with sea-shells, and presenting the appearance of beach, and which fringes the shore at a height far beyond the reach of the tides. Such accumulations have been elevated, and are called raised beaches. And many of these elevations have taken place since the country was inhabited.

Again: the northern provinces of Norway and Sweden are rising: the southern are falling. This gradual elevation has been ascertained by certain grooves being cut in the rocks on the sea-coast, marking the ordinary level of the water on a calm day. Fourteen years afterwards the spot was visited, and, under precisely similar circumstances, the level taken, it was found to be from 4 to 5 inches lower than before. Fishermen also state that they cannot now sail through many channels easily passed through in their younger days. Many sunken rocks have also become visible. As this rising goes on, in course of time, sea-port towns will become inland.

Numberless physical agencies assist in altering the relative distribution of land and water. The soft breezes which blow at evening from the boundless ocean, the gentle shower which refreshes the thirsty earth, and where the heat and light emanate from

the sun, have some influence in carrying on that constant series of changes observed on every hand by the man who devotes himself lovingly to the investigation of nature. It is so common an error to suppose that the most violent causes are the most destructive, that but few persons would imagine rivers to be more active than the devastating volcano in changing the appearance of the surface of the earth. Time and persevering activity effect more than casual impetuosity: a statement which is as true in relation to mind as to those agents which act upon matter. The volcano whose periods of activity may be separated by centuries, produces, when excited, terrible effects upon the district; but the river ripples along its course day after day, and is every hour bearing to some distant sea a portion of the material it has collected.

PART II.—THE AIR.

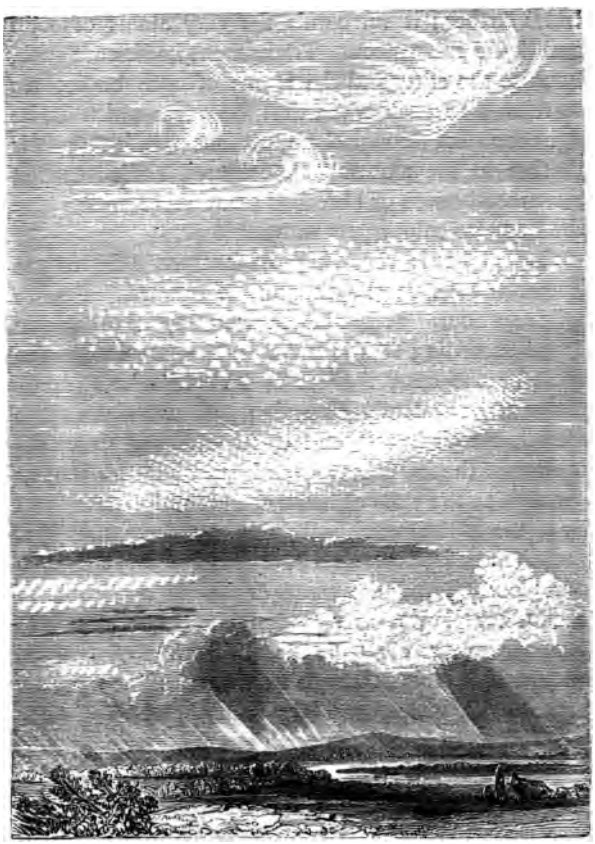
"THE HEAVENS DECLARE THE GLORY OF GOD, AND THE FIRMAMENT SHOWETH HIS HANDIWORK."

CHAPTER I.

ITS PHYSICAL CONSTITUTION.

WE who have been for so long a time with our thoughts directed earthward, must now turn them towards the sky and look into the mysteries of the blue heavens above us. Can philosophy inform us, then, upon the changes which take place in the invisible sea of matter which on every side surrounds us? Thanks to the well-directed labours of talented men, so far as it relates to the air is fairly understood, although much yet remains to be done.

Modern science has proved that some other worlds are provided with atmospheres suited for them, but what is called "space" is occupied by a substance, almost infinitely elastic, through which the pulses of light make their way; and, as Tyndall further says, there is no more difficulty in conceiving this *ether*, as it is called, which fills space, than in imagining all space filled with jelly. It makes the universe a whole, and renders the intercommunication of light and



THE AIR.

VARIOUS FORMS OF CLOUDS.

energy possible. But the subtle substance penetrates farther; it surrounds the very atoms of solid and liquid substances. Transparent bodies are such, because the ether and the atoms of such bodies are so related to each other, that the waves which excite light can pass through them, without transferring their motion to the atoms. In coloured bodies certain waves are broken or absorbed; but those which give the body its colour pass without loss.

Our globe is revolving on its own axis, at the immense rate, at the equator, of upwards of 1,000 miles an hour. It is also moving in its orbit at a speed exceeding 68,490 miles in the hour. Now if such be the case, if there is a vast air-empty space above us, constantly attracting, or endeavouring to attract, our air into it, and if, in addition, the rapid motion of the earth has a tendency to scatter its airy garment to the ends of heaven, as it undoubtedly has by virtue of the centrifugal force, by what power is it that the atmosphere nevertheless still closely clings to our globe? And the same inquiry is applicable to such other planets as may be thus provided. The atmosphere travels with us, as with them, at an enormous velocity, through an airless region; yet no particle of it leaves us. Why is this?

The reason is that the earth exerts upon the atmosphere, as well as upon every liquid or solid body on its surface, the influence of the attraction of gravitation. This force, which pervades the whole created universe, and enchains worlds and systems lying beyond the ken of unassisted mortal eye, holds this elastic and delicate robe, and binds it fast about the

earth. As we travel, it travels. As we revolve, it revolves with us. In fact, could the globe for the space of one hour continue its revolution on its own axis, while the air stood still, the resistance offered by the air to the passage of the earth would be such as to produce, to all appearance, such a tremendous blast, as would not only level trees and houses, but would lift men and animals, and every movable thing into the air, hurling them in a common destruction against the first mountain range that might present itself. Simple and interesting as the fact is, it is greatly lost sight of in our thoughts. We are apt to imagine that the earth moves through the air, not that it carries the air together with it. Were it otherwise only for a little while, the fair landscape at our feet would be turned into such a scene of desolation and destruction as the eye of man has never rested on. It will be necessary to revert to the force of gravitation exercised on the air, with the view to explain a part of the phenomena of the trade winds, on another occasion.

Looking upwards into this vaulted firmament, we seek in vain, by the eye, to learn its actual height. Lying at the bottom of this sea of air, we endeavour, without success, to obtain a measure by which some just conception thereof may be formed. As it rolls its thin waves above us, bearing at an immense altitude, apparently, those clouds which seem set there to tell us how immeasurably deep is the aërial ocean, and as we vainly seek some limit where the surface of the air might be supposed to lie, the inquiry presents itself, Has the atmosphere any actual limit?

The belief in the illimitableness of the air is now generally considered to have been proved to be erroneous. The investigations of philosophers make it appear probable that the extreme limit of the atmosphere does not reach much beyond fifty miles.

The condition of things on the surface of the air is, admitting its bounds, one of a very peculiar kind. Instead of extending to an equal distance from the earth in every direction, it is irregular upon its outer or remote surface, so that an observer who could be placed outside of it and could see it, would perceive this remote surface, like that of a sea thrown into wave-forms, into ridges and dimples of different extent and magnitude. As in the case of a sea, the tendency of the disturbed atmospheric surface is to regain quiescence, and in the meanwhile the gradual equalization of the varying pressures is the cause of winds, upon which all other weather changes are directly or indirectly dependent. The area of atmosphere which has a depression for its centre is called a cyclone, and that which has an elevation for its centre is called an anti-cyclone. If we take our notions of them from the somewhat analogous phenomena which may be seen by watching the swirl of a flowing river, it will become plain that neither cyclones nor anti-cyclones can ever be really symmetrical. Their shapes must undergo perpetual modifications from the pressure and movement around them; and although they are carried on in courses more or less definite, these courses are so often disturbed by surrounding influences that they cannot be predicted with certainty. Hence, although

the cyclones may pursue some given course for thousands of miles, they are none the less liable to be deflected from this course at any time, and by forces which are at present only imperfectly understood.

Upon each square inch of surface at the level of the sea the air presses with a weight of nearly fifteen pounds (14¾ lbs.). In spite of this great pressure a soap-bubble floats safely through the air, and this by reason of the fact that the pressure is transmitted equally in all directions. It is not so with solids, for they press downwards only. Fluids, on the contrary, under which name we include both liquids and gases, press upwards as well as downwards, and so the pressure of the atmosphere, when calm, is unfelt, because the downward pressure is balanced by the upward.

"There's not a breath of wind upon the hill."

The amount of this atmospheric pressure was first ascertained by the celebrated Italian philosopher, Torricelli, whose attention was called to it by the following circumstance. In sinking a well at Florence, in 1643, it was found that after reaching a certain depth the common suction-pump ceased to bring water to the surface. It had been previously known that when a tube was dipped in water, and the air above it withdrawn, the water would rise in it to a very considerable height; but the only explanation of the phenomenon that was offered was the vague assertion that nature abhorred a vacuum, and that the water rose in the tube to fill the vacuum caused by the exhaustion of the air.

The attention of Torricelli having been called to the fact that the water in the suction-pipe of the pump would not rise beyond a height of nearly 34 feet, it occurred to him that its rising at all was to be attributed to the pressure of the atmosphere external to the pipe, forcing the water to occupy the vacuum caused by the exhaustion within it. Torricelli presumed that, as the volume of water was sustained by the pressure of the air, the two must exactly balance each other; and, therefore, that a volume of water 34 feet high must be of equal weight with a similar column of the whole height of the atmosphere. Supposing this to be the case, then, a denser fluid substituted for the water ought to rise in the exhausted tube, less than the water, in exact proportion to the greater density of the fluid employed. To test this theory Torricelli filled a glass tube, 3 feet long, and closed at the end, with mercury, and inverted it in a tumbler containing the same liquid metal. The mercury immediately sank some 6 inches, leaving a column 30 inches in height. Now as the weight of the mercury is 13½ times greater than that of water, the truth of his conjecture was fully proved, viz., that the weight of a column of the atmosphere was equal to a similar column of water 34 feet, or of mercury 30 inches high. Thus was invented that most valuable instru-

THE BAROMETER

ment, the barometer. As the range of the rise and fall of the mercury, at the level of the sea, never exceeds or even reaches 3 inches, the division of the scale is made only on that part of the column between 27 and 31 inches.

The vacant space above the quicksilver in the closed end of the tube is called the Torricellian vacuum, on account of its freedom from air.

Should the weight of the column of air be by any means diminished, the fact will be immediately exhibited by the mercury falling; should it be increased, it will rise. In other words, when the weight of the column is greater it counterbalances more, and when lower, less mercury in the tube.

Elevation produces a similar depression, the barometer falling gradually for every step of ascent gained. A great degree of rarefaction is met with at heights quite within man's capacity of attainment. Travellers on the high lands of South America relate that they experienced the most distressing symptoms in consequence of the extreme tenuity of the air: these were, great difficulty of breathing, uneasy symptoms in the head, and loss of muscular power. Mr. Darwin informs us that he himself experienced this sensation, which is called by the natives the *puna*. Strangers who come to reside in some of the villages, situated at the elevation of from 10,000 to 12,000 feet above the sea-level, do not get over the sensation for almost a year. The natives of the Himalayas ascribe the difficulty of breathing experienced in the higher Alpine passes, 15,000 to 16,900 feet above the sea, to the exhalations of poisonous plants. It is in reality

due simply to the rarefaction of the air, and, therefore, to the diminished pressure. Gay Lussac ascended in a balloon to the height of nearly 22,000 feet above the earth. In these lofty regions the gas of his balloon expanded so much as to require the relief of the safety-valve, and he himself underwent the most acute sufferings from the intensity of the cold and extreme rarity of the atmosphere. Even birds flying over the summits of lofty mountains are said to labour greatly when they reach the highest point, and pigeons dropped from balloons at great heights fall like stones to the earth.

If, then, it were possible to rise to the very surface of the atmosphere, not a drop of the mercury would remain in the tube. This fact is of the utmost importance in the measurement of heights, and proper formulæ exist by which it is easy to ascertain, after certain corrections are made, the amount of perpendicular elevation possessed by a mountain or other eminence.

But, were we to descend with the barometer into the earth, so increasing the depth of the column of air, and therefore also its weight, it would rise in proportion as we descended. So, also, any cause acting in the upper regions of the air to increase the weight of the column would produce the same effect.

For it is one of the curious and interesting discoveries of modern meteorology that the airy ocean is agitated like that of water by TIDES. These are apparently of two kinds, the first being the result of the heat of the sun's rays, the second being due to the attraction of the moon. The atmosphere is

heated to some extent by the transmission of the heat-rays from the sun through it, but chiefly by contact with the earth heated by the sun. Air when heated expands, and becomes lighter; it therefore rises. By this law, the occurrence of the aërial tides is easily and simply explicable. The way in which the fact is observed is by noting at different periods of the day the height at which the mercurial column stands in the barometric tube. Between the tropics the ebb and flow of the atmosphere is one of the most remarkable of phenomena. The periodic rise and fall of the barometer in these regions is owing to the ebb and flow of the atmospheric tides. The variations occur daily in the following order, according to Humboldt:—Twice a day the barometer indicates the highest pressure, or, as we might say, the flow of the tide at 9, or $9\frac{1}{4}$ a.m., and at 10, or $10\frac{3}{4}$ p.m.; and twice a day the lowest, at 4, or $4\frac{1}{4}$ p.m., and 4 a.m., or nearly the hottest and coldest hours in the round of the twenty-four. It is specially remarkable that this periodic rise and fall in the atmospheric ocean takes place in the torrid zone of America without sensible disturbance by elevation, winds, storms, rains, or earthquakes. Such, in fact, is the regularity of this phenomenon, that the hour may almost be told by looking at the column of mercury, instead of the clock. It has also been observed that in Europe the same phenomenon takes place, but is affected to a great extent by the season. In winter the highest pressure takes place about 9 a.m. and the lowest about 3 p.m., after which the pressure again increases up to 9 in the evening. In the

summer these periods are slightly different. It is, however, very difficult to distinguish the occurrence of these aërial tides, in consequence of innumerable accidental causes which disturb their indications. The explanation of the phenomenon arises out of what has been said as to its periods. At the hottest part of the day the air expanding, ascends, and passes over into neighbouring regions; the barometer therefore falls at the "ebb" of the tide. The pressure of the overlying masses of cool air keeps the column up, at its highest point, at the coldest part. The barometer, therefore, rises with the "flow" of the tide.

But the hourly observations of the barometer made, for some years past, at the Meteorological and Magnetic Observatory at St. Helena, have also placed beyond a doubt the existence of a lunar atmospheric tide. It appears that on each day the barometer at St. Helena stands on an average $\frac{4}{1000}$ of an inch higher at the two periods when the moon is on the meridian, above or below the pole, than when she is six hours distant from the meridian on either side, the progression between this maximum and minimum being moreover continuous and uninterrupted. We are thus reasoning, from the position of the mercury in the barometer, as to the position of the heavenly bodies, which, unseen by us, are influencing its visible fall and rise.

A phenomenon yet more extraordinary is that of ATMOSPHERIC WAVES. As yet the discoveries are incomplete; but we know that not mere undulations of a slight extent, like those of the surface of the sea, but great wave-like movements, pervade the whole

depth of the atmosphere, and occupy several days in their duration. The most remarkable of these is a vast wave which has for several years been observed about the middle of the month of November. It lasts, with some modifications, for about sixteen days: that is, it begins, rises higher and higher, until it reaches its highest point, then subsides again, and the atmosphere returns to its usual condition in the space of fourteen to sixteen days. Sometimes it has been observed to set in with a gale of wind, and to end with one. As a curious coincidence, it has been remarked that the period at which this great November wave is at its highest point in our country is precisely that given by American travellers for the occurrence of that most remarkable meteorological phenomenon, the Indian summer. In America, at this period, generally from the 12th to the 17th of November, after a foretaste of the severities of winter has been felt, a sudden change of temperature takes place—a delicious warmth ensues, the sky is without a cloud, not a breath of air is stirring, and the whole atmosphere is filled with a glowing, transparent haze. In three days this is all gone, and winter comes on quickly afterwards. In Switzerland, the same phenomenon has been remarked from time immemorial. About the 11th of this month the *fête* of St. Martin is celebrated, and the inhabitants call the delightful four or five days' return of summer weather, at a time when the summer has ended, *l'été de St. Martin*, or St. Martin's summer. The method of estimating the pressure of the watery vapour, independently of the gaseous atmosphere, is by calculations based upon an ingenious little

instrument, called Daniell's hygrometer, which will be noticed under the head of dew (p. 175).

Although not sensibly felt, the pressure of the air is of great consequence to our well-being, and is also highly necessary to that of every living thing and to the preservation of natural things. To ourselves it is important in many ways: thus it prevents that excessive evaporation from the surface of our bodies which would otherwise exhaust our frame. It also determines in an important manner the proper density of the volume of air which is requisite for our comfortable breathing: hence the laborious respiration of persons at high elevations. It is important also to us in an economical point of view: it is found for instance that if we, by any method, diminish the pressure on the surface of liquids, as, for example, by exhausting a part of the air from a close vessel, that they will boil at a much lower temperature than when the full pressure of the atmosphere is allowed to exert itself upon them. In sugar-refineries this is taken advantage of by boiling down the sugar in pans from which the air has been exhausted by a steam-engine; in this way the production of much uncrystallizable treacle, as also all risk of burning, are avoided. Again, if the pressure is increased, the boiling-point rises also, and it will be more difficult to bring liquids up to this point. Indeed, a liquid is said to boil when the vapour which comes from it is equal to the pressure upon it. When the pressure is greater than the ordinary pressure, and which is said to be equal to a column of mercury 30 inches in height, the liquid to be boiled has to

lift a greater weight. Boiling may therefore be regarded as the lifting of a weight.

As a curious result of the diminished pressure lowering the boiling-point, it may be mentioned that much inconvenience is occasionally felt by travellers on high mountain regions. Darwin relates a humorous anecdote of this nature; he was at that time travelling in the Andes: "Our potatoes, after remaining for some time in the boiling water, were nearly as hard as ever. The pot was left on the fire all night, and next morning it was boiled again; but yet the potatoes were not cooked. I found out this by overhearing my two companions discussing the cause; they had come to the simple conclusion that the potatoes were bewitched, or, that the pot, which was a new one, did not choose to boil them." The Monks of St. Bernard, living as they do at an elevation of 8,034 feet, are sorely distressed at the same phenomenon and are compelled to subsist almost entirely on fried, roasted and baked food, in consequence of the water boiling at so many degrees under the ordinary boiling-point (212° Fahrenheit or 100° C, the barometer being at a height of 30 inches), as to render its heat insufficient effectually to cook the food which they procure. If this statement should be true at the present time, it seems a pity no kind traveller should have carried a Papin's digester to them; for, as that is a close vessel fitted with a pressure valve, they could easily remedy the inconvenience under which they labour, by substituting an artificial pressure in place of the deficient atmospheric weight.

The density of the air is in the inverse ratio of the pressure. In other words, as half the pressure means double the volume, and double the pressure, half the volume, it is easy to conceive how important it must be, for the feathered tribes, that the air should be sufficiently dense to offer resistance to the play of their pinions. So also, though in a less degree, to insects. Some birds taken upon one occasion by an aëronaut in a balloon to a great height, and set at liberty, refused to leave the machine and clung to its sides in terror, being apparently sensible that the air was too thin to support the weight of their bodies. To fishes, the atmospheric pressure is also of vital consequence. If this pressure were removed, the result would be that the air now dissolved by water would immediately rise from it, and the inhabitants of our lakes, rivers and seas would die, in consequence. To plants it is also of great moment; the pressure restrains that excessive loss of fluids which would follow if it were in any degree removed. For, just as diminished pressure lowers the boiling-point (in the imperfect vacuum of an air-pump water boils at 67° Fahrenheit), so it increases the facility with which the evaporation of fluids takes place. In various ways atmospheric pressure exerts a beneficial influence upon their growth and functions, and upon the motion of the vegetable juices.

If we place a piece of solid ice under the exhausted receiver of an air-pump, and take care that the experiment is conducted in a room below freezing-point, so as to insure its not melting, we shall find in a little while that all the ice has disappeared; the reason

will be, that it has evaporated. From this we may learn, that if the atmospheric pressure were removed, not only would liquids evaporate, but also many solids. From these considerations we may learn the wisdom and beautiful adaptation to existing conditions exhibited even in the apparently unimportant particular of atmospheric pressure.

There is yet another circumstance to be noticed in reference to the physical constitution of the atmosphere, and that is, the temperature of its higher regions. It has been mentioned, that in proportion as we rise from the earth, the density of the air becomes continually less and less. The balloon of the aëronaut, after rising to a certain height, can rise no longer. It then remains stationary, for above it the air is so thin as to be unable to support it, with its car and weights, even in spite of its buoyant contents of hydrogen gas. This effect is due to the elasticity of the air. In proportion as the pressure on its particles diminishes, their tendency is to separate farther and farther from each other; or, in other words, the air expands. By calculation it has been found that this expansion of the air as we ascend takes place in what is called a geometrical progression. For instance, if at the level of the sea a certain quantity of air occupied 1 square foot of space, at about three miles and a half it would fill a space of 2 square feet; at about seven miles, 4; at about ten miles, 8; at thirteen miles, 16; at seventeen miles, 32; and at twenty miles, 64 cubic feet. Hence we very soon reach a limit by means of the balloon beyond which we cannot pass.

The limit appears to be about 22,000 feet; that, at least, is the highest point yet attained in aërial navigation.

Now it is a remarkable fact that one of the consequences of this expansion is a diminution of temperature.

Sir H. Davy refers to a machine at Schemnitz, in Hungary, in which air was compressed by a column of water 258 feet in height. When a stop-cock was opened so as to allow the air to escape, a degree of cold was produced which not only precipitated the watery vapour diffused through the air, but caused it to congeal in a shower of snow, while the pipe from which the air issued was surrounded with icicles. "Dr. Darwin," writes Davy, "has ingeniously explained the production of snow on the tops of the highest mountains, by the precipitation of vapour from the rarefied air which ascends from plains and valleys. The Andes, placed almost under the line, rise in the midst of burning sands; about the middle height is a pleasant and mild climate; the summits are covered with unchanging snows."

Under the air-pump, we can produce a great degree of cold, because the expanded air requires heat and draws upon surrounding bodies. By the little contrivance represented in the cut we may readily manufacture a small quantity of ice. A little water must be put into a watch-glass, supported by a triangle of

wire over a saucer of oil of vitriol, placed over the plate of an air-pump, and covered by a flattened receiver; the pump being then worked, the water will in a few minutes be converted into a mass of ice.

A machine has been patented in America for making ice by the expansion of previously compressed air. It consists of a kind of steam-engine, and at every stroke produces a shower of snow. Something of the same kind is witnessed when a bottle of soda-water is opened: the compressed carbonic acid requires heat in order to expand and escape. This heat it obtains from the watery vapour of the air which is rendered visible as a cloud resembling smoke. Ice is also obtained by exposing water to the cold produced by the evaporation of ether or of ammonia, the apparatus being so arranged that the same ether, or ammonia is employed over and over again.

The cold of the upper regions of the atmosphere is in part due to the loss of heat by radiation into space. This loss of temperature must be familiar to every visitor of mountain scenery. Frequently it is picturesquely painted by the snowy cap which envelopes the summits of the loftiest mountains; and where the mountains are of the most elevated description, at a certain height there is a distinct line, visible from afar, and forming a very peculiar feature of landscape, which is well known as "the line of perpetual snow." It is, in fact, in most cases an almost straight line between the fringe of hardy and scanty vegetation and a snowy covering which clothes the mountains from its summit to that point. This appearance sufficiently indicates, by a sort of natural thermo-

meter, the temperature of the air at such elevations. The line varies in height in different countries; and although highest in hottest countries, as at the equator, as a general rule, and becoming lower as we approach the poles, when it enters the earth, this law is by no means without its exceptions, some of which are of a very singular character.

Of these exceptions, one of the most remarkable that have recently presented themselves is the account given by a missionary, Mr. Rebmann, of a supposed snow-covered mountain in Eastern Africa. This discovery is mentioned in the following extract from his journal:—"The mountains of Jagga gradually rose more distinctly to our sight. At about ten o'clock I observed something remarkably white on the top of a high mountain, and at first supposed that it was a very white cloud, in which supposition my guide also confirmed me; but having gone a few paces further, I could no longer rest satisfied with that explanation; and while I was asking my guide a second time whether that white thing was indeed a cloud, and scarcely listening to his answer that yonder was not a cloud, but what that white cloud was he did not know, but supposed it was *coldness*, the most delightful recognition took place in my mind of an old European guest called *snow*. All the strange stories we had so often heard about the gold and silver mountain Kilima dja āro, in Jagga, supposed to be inaccessible on account of evil spirits, which had killed a great many of those who had attempted to ascend it, were now at once rendered intelligible to me, as, of course, the extreme cold, to which the poor

natives are perfect strangers, would soon chill and kill the half-naked visitors."

Further on Mr. Rebmann writes,—"May 12, at about five o'clock, P.M., we had to ford another river called Gona, which was considerably larger than the Loomi, its breadth being from 30 to 40 feet, and its depth 3 feet, with a most rapid stream. Its water was cold enough to prove its source, which evidently is nothing else than the eternal snow of the Kilima dja āro." Mr. Rebmann adds to these remarks some particulars, respecting a large exploring party sent by the late king of the country, to "examine into the nature of that strange white guest in the neighbouring mountain, when only one man was spared, though with his hands and feet destroyed by excessive cold, to tell his despotic sovereign the sad tidings of all his companions having perished in the expedition."

Although loosely stated, the account of this mountain is considered by many to be accurate, and if so, it undoubtedly forms one of the most remarkable exceptions to the general rule, with regard to the temperature of high air in the tropics. By ordinary calculations, a mountain in East Africa, to be covered with perpetual snow, must approach 16,000 feet in height; and it is by no means clear that Kilima dja āro approaches this degree of altitude. The mean height of the line of perpetual snow is at the equator 15,200 feet.

The accompanying cut exhibits the elevation of the snow line in different latitudes from the equator to the poles. In its composition, Johnston's "Physical Atlas" has been consulted.

We are accustomed to say that the air is transparent. Mr. Darwin mentions the fact that, "while ascending the Bell mountain in central Chili, the evening was fine, and the atmosphere so clear that the masts of the vessels at anchor in the Bay of Valparaiso, although no less than twenty-six geographical miles distant, could be distinguished clearly as little black streaks." But, in truth, the air is neither perfectly transparent, nor entirely colourless, when seen in bulk. As we ascend, the colour deepens, in consequence of the dark space beyond our atmosphere being seen through it more distinctly, and at the great elevations which have been attained, by means of the balloon, it almost

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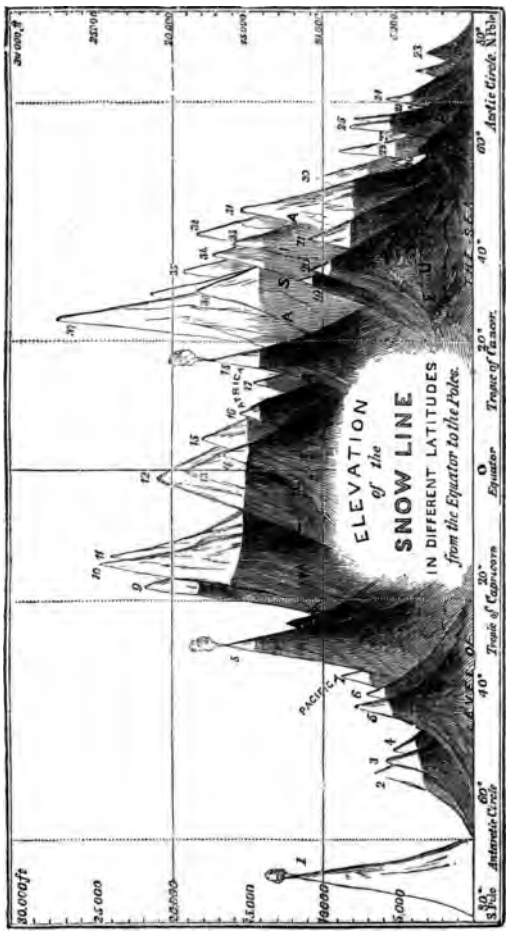
REFERENCE TO OPPOSITE CUT.

1. Erebus.
2. Sarmiento, Tierra del Fuego
3. Nose Peak, Tierra del Fuego
4. Mount Stokes, Patagonia.
5. Yanteles, Andes of Chili.
6. Osorno, Andes of Chili.
7. Egmont, New Zealand.
8. Vol de Peuquenes, Chili.
9. Gualatieri, Western Cordillera.
10. No. de Sorata.
11. E. Cordillera.
12. Chimborazo, Quito.
13. Cotopaxi.
14. Purace.
15. Tolima.
16. Sierra Nevada de Marida.
17. Abba Jaret, Abyssinia.
18. Popocatepetl.
19. Sierra Nevada.
20. Etna.
21. Pyrenees.
22. Ben Nevis.
23. Mageröe.
24. Sulitelma, interior of Norway.
25. Osterjokul.
26. Interior of Norway.
27. Northern Ural.
28. Kamtschatka.
29. Oonalashka.
30. Altai.
31. Mont Blanc.
32. Elburz, Caucasus.
33. Kasbek, Caucasus.
34. Ararat.
35. Bolor.
36. Hindoo Koosh.
37. Dhawalagiri, Himalaya.


ELEVATION
of the
SNOW LINE
IN DIFFERENT LATITUDES
from the Equator to the Poles.
ASIA
EUROPE
AFRICA
PACIFIC
OCEAN
Antarctic Circle
Tropic of Capricorn
Equator
Tropic of Cancer
Arctic Circle

approaches black. On the summit of high mountains it is often seen to be of an intense Prussian blue. M. de Saussure made some singular observations upon this subject, and formed a scale of the shades of colour as we ascend. In Coleridge's sublime lines, entitled the Alpine Hymn, this fact is alluded to in speaking of the "Sovran Blanc:"

> "——— Around thee and above
> Deep is the air, and dark, substantial black,
> An ebon mass. Methinks thou piercest it
> As with a wedge."

Sometimes the blueness becomes very remarkable. The following letter describes a most curious example of the occurrence of this phenomenon at Bermuda:— "On the 10th of August, 1831, the weather," observes the writer, "was remarkably fair; but as evening drew near, a change took place. The sky began to lower, and put on an awful and gloomy appearance. The clouds collected voluminously, and very heavily, in every direction over the island, indicating a prodigious fall of rain. At this time I do not recollect any threatening of a storm of wind, save a moderately hollow sound of the sea dashing against the shore, but by no means equalling that which we frequently witness at this season of the year, when a storm is impending, or has passed by us. Thunder and lightning began to be severe, and the weather more threatening. Next morning, the 11th, I rose early for the purpose of writing, and soon discovered the light was so dim that I could not proceed. I removed to another room, and finding my situation not improved, I said, in the presence of one of my family, I appre-

hended a sudden failure of sight. I was then asked if I had not observed a very peculiar appearance of the sun's rays the day before. I had not; but had perceived the floor of the room to look *blue*, especially where the sun shone on it: indeed, every object in the room appeared of a sickly blue colour. The next day, the 12th, a mail-boat was put under weigh, for the first time, with a party on board. The day was so mild and tranquil we could only reach a few miles: the sails, which were new and pure white, nevertheless appeared to be stained of a bluish colour, and the sea was of a dingy yellow. On the first arrival from the West Indies, we heard of the devastation at Barbadoes; but with us there were no subsequent unusual appearances; on the contrary, we had very fair weather, although I heard this singular blue colour was observed even to the coast." This letter was read by Sir D. Brewster, at the tenth meeting of the British Association, and in alluding to the cause of the phenomena, he expressed the conviction that the blue colour was produced by the interposition of water, in the form of vapour, between the sun and the observer.

It has been ascertained by M. Arago, that the light reflected from the sky is in the peculiar condition known as *polarized*, exhibiting different effects from that of the direct rays of the sun. Upon one of the peculiar phenomena exhibited by the polarized light of the sky as the sun changes its position during the day, Professor Wheatstone has constructed what he calls the *Polar clock* or *dial*. It is impossible in this place to enter into an explanation of the prin-

ciples upon which this beautiful invention depends, as it would be unintelligible without a full discussion of the difficult subject of polarization of light; but it may be stated, that by its means the time may be most accurately ascertained, simply by directing the instrument to the North Pole of the sky. It is found that it will indicate the time even before sunrise and after sunset; in fact, so long as the rays of sunlight are reflected from the atmosphere.

The beautiful and gorgeous colouring of clouds depends upon the decomposing effect of their watery particles upon the rays of the sun. In tropical countries there is a peculiarly beautiful appearance in the atmosphere which we do not meet with in temperate zones. Baron Humboldt frequently alludes to it as a sort of thin haze or vapour, which, without changing the transparency of the air, renders its tints more harmonious, and softens its effects. This appearance was also noticed by Mr. Darwin. "The atmosphere," he says, speaking of Bahia in Brazil, "seen through a short space of half, or three-quarters of a mile, was perfectly lucid, but at a greater distance all colours were blended into a most beautiful haze, of a pale French gray mixed with a little blue. The condition of the atmosphere between the morning and about noon, when the effect was most evident, has undergone little change, excepting in dryness."

The atmosphere contains a store of electricity, which acts in various ways an important part toward both organic life and inorganic matter. The whole vegetable and animal world are largely influenced by this electricity, and it is doubtless intimately con-

nected with their life and well-being. It is also greatly concerned in the formation of clouds, rain, and similar phenomena. When developed in intensity, as in the explosions accompanying tempests, it effects various chemical decompositions in matters present in the air. It has been considered that ammonia may sometimes be produced by its influence. It also produces small portions of nitric acid, and indeed it is a rare thing to meet with rain-water in which distinct traces of ammonium nitrate may not be detected. The services of electricity are numerous: some of the oxygen of the atmosphere is being constantly converted by it into a more active condition of that element. Friction of particles of water against each other, evaporation, and the chemical decompositions which take place on the earth's surface, all are productive of electricity. When the air is clear, it is generally positive; this, however, varies with the source. The earth, on the contrary, is always charged with negative electricity.

With these remarks on the physical characters of the atmosphere and its connected phenomena, we may pass on to the Chemistry of the Air.

CHAPTER II.

CHEMICAL CONSTITUTION OF THE AIR.

DIFFICULTIES which appeared quite insurmountable had long beset the investigations of chemists upon the composition of the air. Long after the revival of experimental Chemistry the most erroneous impressions were afloat, and chemists, in their discordant analyses, only increased the confusion by the vast discrepancies which occurred between the results of one analyst and those of another. Until the middle of the eighteenth century the opinion was very prevalent that the atmosphere formed one of the four elementary bodies; that it was, in fact, a simple, undecomposable gas. It was reserved for the talented Dr. Priestley to dispel this error. He discovered the existence of a new gas which formed one of the constituents of air. In this gas it was found that combustion took place with extraordinary intensity; even iron wire, heated red-hot and plunged into it, caught fire, and burnt away. Other combustibles gave out showers of the most brilliant sparks and produced the most intense heat when placed in the jar containing it; a lighted taper having been blown out, immediately rekindled when put into it and blazed with much greater brilliancy than in air.

These extraordinary characters soon gave the gas great celebrity.

Another gas was also found to form a component of the air, one in direct contrast to the former. Instead of increasing the brilliancy of flame, it extinguished it as effectually as so much water. Like oxygen, it was inodorous; but whilst the former exhibited the utmost greediness for combination, nitrogen was indifferent to almost everything. Animals were exhilarated when plunged into oxygen; they were suffocated in nitrogen. Such were the opposing qualities of oxygen and nitrogen.

Thus the bare fact was shaped out: air is not an element or a simple body, but a mixture of oxygen and nitrogen.

The investigation of the composition of the air was attended with unusual difficulties, but the principles adopted by different analysts were very similar. Thus, the energetic character of the gas oxygen is in striking contrast to the inertness of nitrogen, and this fact was taken advantage of by chemists. It was easy to select substances which seized the oxygen, while the nitrogen was left wholly uninfluenced by their presence. To enumerate a few: we find phosphorus, moistened lead turnings, mercury, sulphide of potassium, and hydrogen employed. Phosphorus, when exposed, readily absorbs oxygen from the air, and leaves all the nitrogen. The method of conducting the experiment may be shortly stated:—

A portion of air should be confined in a glass tube, over distilled water, and in it a small piece of phosphorus, fixed to the end of a wire, should be placed.

The tube should be graduated into a number of divisions, by which the height of the contained water may be ascertained. After the lapse of some hours the water inside the vessel will be found at a higher mark than before. This indicates that a certain amount of air, equal to the amount of increase in the height of the water, has been abstracted. After a time the water ceases to rise, and then the process is complete. On removing the jar and putting a lighted taper into the remaining air, it will be found to go out directly, and a small animal would be suffocated by it. These are not the characteristic effects of oxygen; the residue is therefore nitrogen, the oxygen having entirely disappeared. The calculation is now easy,—the raised level of the water indicates the amount of oxygen removed, and nearly all the rest is nitrogen. Such was the simple analysis which was long considered best for the determination of this point. This process was called eudiometry, which signifies the measuring of the beneficial principle (oxygen) of the air.

EUDIOMETER.

But in this plan the solvent power of water for oxygen, the uncertainty whether the *whole* of this gas had been completely removed, with several other causes of error, interfered with the result; and we may, in the recollection of these errors, satisfactorily point to the real source of these analytical inaccuracies which had long perplexed chemical science.

To place this subject on a sounder basis was felt to be a national object by Messrs. Dumas and Boussingault, two of the most eminent chemists of the French school. They resolved to attempt to remove the stigma from Chemistry, and to determine finally the true chemical constitution of the atmosphere. Impressed with this idea, they conceived a method of analysis of perhaps unparalleled ingenuity and accuracy, in the employment of which every conceivable source of error appears to have been guarded against. The following account of it is derived from their own memoir, published in the *Annales de Chimie et de Physique:—*

The air selected for analysis was collected in several large glass flasks, which were first entirely exhausted of air by means of a very powerful and perfect air-pump, the vacuum being properly tested before the vessels were used. On arriving at the proper locality the mouths of these vessels were opened, the air immediately rushed in and filled them; they were then closed and conveyed to the laboratory, and the analysis of the air was commenced. One of these flasks was connected with the tube of the analyzing apparatus; and at the opposite end of the apparatus was attached a similar flask, only perfectly vacuous. By this means it was intended that the air of the first flask should be drawn through the apparatus into the second. The flasks and whole apparatus were now carefully weighed. The stopcock of the vacuous flask and that of the one filled with air were then opened, thus causing the air from the one to pass on to the

other through several liquids, in which its watery vapour and other impurities were arrested, and finally over metallic copper, finely divided, and heated to redness, a substance which has the remarkable property of instantly arresting and absorbing every particle of oxygen from the air as it is passing over it. Thus at length nitrogen only remained, and passed on into the flask. After the process was completed the apparatus was again weighed. By this means the amount of oxygen in the whole quantity of air that had passed through was accurately ascertained, as by uniting with the copper it gave additional weight to the apparatus, consequently all that was necessary to ascertain the precise quantity of oxygen in the flask of air was to find out how much the copper had increased in weight; all the grains of increase represented grains of oxygen. Since these results were obtained, other methods of analyzing the air have been devised and perfected, and recourse again had to the eudiometer, mercury being substituted for water, and the oxygen being removed by combining it with hydrogen, and separating the water thus formed.

The result of a large number of experiments, although occasionally some striking variations, possibly owing to errors in the analysis, have been noticed, gave an average which exhibits the composition of the air in the following proportions:

One hundred measures of dry air consist of, by volume—

Oxygen	20·8
Nitrogen	79·2
	100·0

This question was therefore at length satisfactorily decided. But it had often been much disputed by philosophers whether air was universally of a similar composition. Is it the same in the loftiest regions as it is on the level ground, on Mont Blanc, or Chimborazo, as on the sea-shore? When the facts are inquired into, it seems certain that such is the case! Gay-Lussac, by means of a balloon, brought down air in a vessel from a height of between three and four miles. On being analyzed, it was found to be in no respect different from the air of the lower strata of the atmosphere.

A portion of air collected by Mr. Welsh, in August 1852, at a height of 18,000 feet, in one of the balloon ascents undertaken by him and Mr. Green, under the direction of the Kew Committee of the British Association, contained 20·88 per cent. of oxygen by measure, while air collected at the same time on the surface of the earth contained 20·92 per cent.

Practically, then, the composition of the atmosphere as regards oxygen and nitrogen is perfectly uniform, when proper allowance is made for the greater solubility in water of oxygen. Rain-water and melted snow always contain a larger quantity of oxygen than the air, nearly in the proportion of one volume of oxygen, to two volumes of nitrogen. And this is one of the strong arguments in favour of the atmosphere being a mere mixture of gases, and not a combination. For in a mixture, bodies retain their individual characters, whereas in a combination these are lost. Now no one can assert that either the

oxygen, or the nitrogen in the air has lost a trace of its separate characteristics! Oxygen is a supporter of combustion: the air supports combustion. Oxygen is necessary to respiration: the air supports respiration. An admixture of oxygen and nitrogen, in the same proportions as in the air, is possessed of exactly the same properties, and takes place without heat or alteration of volume. Lastly, if oxygen and nitrogen were combined, we should expect water to dissolve them in the same amounts, at the same temperature, under similar circumstances.

There is sufficient scope for admiring the wisdom and benevolence of the great Architect in the construction of the air. From the difficulty with which nitrogen enters into combination, it is wonderfully adapted for admixture with oxygen. We could not live in an atmosphere of pure oxygen. Respiration is so accelerated, and the destruction of tissue promoted so exceeding the powers of repair, that death would speedily ensue. If we should stay for a moment to consider the enormous loss of oxygen which the atmosphere incessantly endures, thousands of tons of this gas being withdrawn from it year by year, and yet by all attainable evidence we are assured that the composition of the air has not altered from age to age, the reflection comes upon the mind with overwhelming force, how is this loss repaired? What can be that exhaustless spring which pours back the exact equivalent of these abstracted quantities into our beautiful air? Had not some means of its restoration been pre-ordained, there can be no question that a most serious deficiency of this gas would have been

sensible at this period of the earth's history. The Chemistry of creation, however, informs us that a never-failing spring of oxygen exists, and its copious streams, by a nice adjustment, replace by far the greater part of the loss. In this green grass, in the leaves of these unpretending herbs, and in those of the clustering wood, we shall hereafter find are hid those springs of this precious ingredient of our air, without which desolation and death might at no distant time gradually overwhelm our globe.

From the preceding remarks it must not be supposed that the atmosphere is purely a mixture of two gases. Such we may indeed truly consider as the composition of *air*, but by no means that of our atmosphere. Oxygen and hydrogen in chemical union form water, but pure water would ill satisfy the wants of the countless inhabitants of the ocean. So, while we may justly regard oxygen and nitrogen in the given proportions as air, the atmosphere would be totally unfitted to fulfil its present functions, were there no other gaseous ingredients present in it. Indeed, the salts and dissolved gases of the great deep do not stand in anything like the same relation of importance to the tribes which people it, as does the admixture of foreign gases in the air to both man and vegetation. Possibly, had the atmosphere been created for man alone, and could he have existed on a different description of food to the present, it might have been unnecessary to cast any other ingredients into its composition. But the earth was to be adorned with plants, and these were destined to supply man with pure, agreeable, and nutritious food.

Vegetation cannot exist in a pure atmosphere of oxygen and nitrogen for any length of time, much less thrive, blossom, and produce fruit. A provision, therefore, was necessary for its wants. Yet here another difficulty presents itself. The gas which proves most nutritious to vegetation is one which is deadly in its effects on the animal tribes! This gas is Carbonic Acid. The room capable of containing 100 cubic feet of air, if filled with a mixture of 96 cubic feet of air and only 4 of this gas, would be speedily fatal to any human occupant. How was this difficulty to be surmounted? How was vegetation to live, and man not to die? By the most beautiful adjustment this problem has been solved, for it is found that a quantity of carbonic acid gas, which appears disproportionately small, and is in reality so minute as to be altogether without effect upon the human constitution, yet at the same time sufficiently great to meet and satisfy all the requirements of the most profuse vegetation, has been widely mixed with the other gaseous constituents of the atmosphere. The quantity of carbonic acid present in the atmosphere is variable: represented by figures, the proportion varies from 3 to 6 parts in 10,000 parts of air. It increases during a frost, and diminishes when a thaw sets in. In summer it is more abundant than in winter. It increases during the night, and diminishes after sunrise. It is less in amount over large tracts of water than over the land; it is therefore lessened by rain, which dissolves and carries a portion of it to the earth.

Carbonic acid, however, is a remarkably heavy gas; so heavy, that it may actually be poured like water out of one vessel into another, as may easily be proved by filling a jar with this gas, procured by acting on a little chalk (calcium carbonate) with hydrochloric acid and water, and holding it in the position represented over the mouth of another jar containing a lighted taper, which will be immediately extinguished.[1] If at the temperature of 60°, and barometric pressure 30 inches, 100 cubic inches of air weigh 30 grains, under similar circumstances 100 cubic inches of

[1] A very interesting application of this property of carbonic acid gas, mixed with nitrogen, was made by Mr. Gurney. By some accident a large and valuable coal-mine took fire. After vain attempts to quench the devouring element, the galleries were reluctantly abandoned and the miners withdrew with their instruments. There seemed no way of quenching the immense body of fire raging under-ground but by the enormously expensive one of turning a stream of water into the mine, so as to fill it, when the idea was suggested that it might be extinguished just as effectually by means of gas, as of water. Arrangements were then made for conducting the air of a furnace—which consists largely of nitrogen and carbonic acid—after cooling it by passing it through water, down to the workings; and a steam-jet placed over the mouth of the pit was made to act, so as to produce a powerful draught. By this means a

carbonic acid will weigh more than 47 grains. Its tendency, therefore, would be to collect and accumulate near the surface of the ground. This may be seen by anyone who will pay a visit to a large brewery. Standing by the side of one of the large fermenting vats, and in such a position that it may be seen against the light, he will perceive trembling, transparent, floods of this gas pouring over the top and down the sides of the vessel. The same appearance is also frequently visible in a glass of soda-water, which is charged with carbonic acid. This gas, as has been before noticed, is poured into the air in enormous quantities. Why does it not obey the laws of gravity, and remain near the ground? How is it that we find it diffused throughout the atmosphere? This question must be answered by an experiment.

If a glass jar or bottle were filled with carbonic acid, and the mouth stopped by a plug of plaster of

stream of nitrogen, carbonic acid, and other gases was drawn from an apparatus specially contrived for this purpose, passed down the descending shaft, poured out upon the body of fire, and being sucked upwards by the steam-jet, returned again up the ascending shaft. In a few hours the fire was wholly quenched; and after a certain time pure air was blown through the mine: the next day it was inspected; all was found safe, and the workings were resumed. From this may be learnt the value of even a moderate knowledge of chemistry. Phillips's "Fire Annihilator," which is a machine for pouring out a stream of gas upon a fire, and putting it out by excluding the combustibles from the access of the oxygen of the air, acts upon similar principles to this plan of Mr. Gurney's, but the gases evolved are different, consisting of the products of the combustion inside the apparatus of sulphuric acid, chlorate of potash, and sugar, together with some portion of steam.

Paris, and left, in a little time the vessel would be found only to contain common air. The heavy carbonic acid would have entirely disappeared. As there is but one way of escape through the neck, and even this passage is, apparently, very accurately closed, it is evident, whatever the power, it was sufficient to enable this naturally heavy gas to rise up and leave the vessel, and the naturally lighter air has descended and filled it. A pleasing way of performing this experiment is to fill one jar with the lightest of all known gases, hydrogen, and another with the heavy carbonic acid gas, and connect them by two perforated corks and an intervening tube, as represented, and then to place them in the position shown, that containing the hydrogen being uppermost. In a little while the heavy carbonic acid gas will rise to the top of the upper jar, and the light hydrogen will descend, and sink into the lowest jar, until the two jars contain a uniform mixture of both gases. The force which produces this remarkable phenomenon is the diffusive power of gases, the beautiful laws of which were discovered and developed by the eminent chemist, the late Professor T. Graham. By virtue of this remarkable law, the heaviest gases rise up into the air, though less rapidly than the lighter, and, more singular still, actually with as much force as if they were rushing up into a vacuum. Thus they have power to rise to the very highest regions

of our atmosphere, and to spread to its remotest limits.

It would be difficult to select a more striking illustration of the wisdom and design displayed in assigning laws to the atmosphere, and to gaseous fluids in general, than is thus presented to us. The uniformity of the atmosphere is mainly due to the incessant influence of this dispersive force. Diffusion is, as it were, the messenger between man and vegetation, for it conveys to the one the carbonic acid produced, and brings back to the other the oxygen restored. By this means, also, is gradually effected the dispersion of all gases, no matter whether dense or rare. While the heaviest vapours are thus made to rise and spread far and wide, the lighter ones are also caused to descend and intermix with air far more dense than themselves. These are facts which experiment has amply proved.

De Saussure found the heavy gas of which we have spoken (carbonic acid) present in the thin air of the Alpine summits, and even in greater abundance than in the air of the lowlands far beneath, an effect due, without doubt, to the influence of vegetation; thus clearly proving that the mere circumstance of elevation is no obstacle to the force which impels the gas upwards.

The same diffusive force scatters gases abroad, laterally, as well as in the perpendicular direction.

But we owe to diffusion more than this. The balmy air which every now and then comes to us odorous with the simple perfume of the violet, or hedge-row, or with the peculiar fragrance of the new-

mown hay, would be deprived of all its scented properties, and would be felt without pleasure and inhaled without delight, were it not for the power of diffusion. As, while we stand thus discoursing on Nature's Chemistry, we drink in the pure fragrance of such flowers as lie scattered around, and perceive such freshness and delightful property in the air, let us remember that, did not diffusive force lend wings to the fragrant vapours poured out from the flowers, none of these pleasures would be experienced. We see, then, in this force a most powerful agent of intimate, although imperceptible, intermixture of the various gaseous and vaporous ingredients of the atmosphere, whether regular or accidental.

Accurate investigations have made us acquainted with another constituent of the atmosphere, always present, but in variable quantity. The amount of light carbonetted hydrogen is inconsiderable, and it arises from various sources, especially from the decay of vegetable matter. It abounds most in the atmosphere of the fens, and is most probably ever to be met with in tracts infested with ague.

But who that has looked with grateful sense on his fields, a few days since parched and brown, now re-clothed with raiment of freshest green, the herbage springing up with that vigour and luxuriance peculiar to the growth of the tender blade, when the "clear shining of the sun follows rain," would suppose that this sudden verdure owed anything to Ammonia? Still less would one be disposed to admit that our pastures are deeply indebted to a gaseous constituent of the air, so minute in its

amount, as we shall learn, as to have long eluded the search of the most eminent chemists. Not but that ammonia had long been suspected to exist in the air! Philosophers, aware of the numerous sources from whence this volatile compound was disengaged, felt persuaded of its presence in the atmosphere, but were unable to confirm their suspicions. At length, Liebig conceived the happy idea of trying whether it might not be found in rain-water. Since ammonia is very soluble in water, it seemed rational to suppose that, if it really existed in the air, it would be found in the waters of a shower. A considerable quantity was collected and evaporated down carefully. After this operation had been long continued, at length brownish crystals appeared in the fluid. The chemist's search was about to be crowned with success; and to his great gratification on analyzing these crystals, they proved to be the long-looked-for ammonia in the form of an ammoniacal salt.

According to M. Ville 28,000,000 volumes of air contain 1 volume of ammonia. As one measure of water at the ordinary temperature will absorb 727 measures of the gas, it is not surprising that a larger quantity of ammonia is always contained in the rain collected at the commencement of a shower, and that it should almost disappear from the atmosphere after a heavy rain. Nor is it to be wondered at that the ammonia present in fogs and dews is greater than in rain. The proportion of ammonia in rain is liable to considerable variation. Messrs. Lawes & Gilbert found the average amount from

September to February 0.927 parts in 1,000,000 parts, and from March to August 1.142 parts. This was in 1853–54.

In the rain of cities there is more ammonia, as the latter is one of the constituents of respired air, and a product of combustion, decay, and putrefaction. But from whatever source derived, the existence of ammonia in the atmosphere is of great importance. Chemically, it is a compound substance, formed of, by volume, three of hydrogen, and one of nitrogen; these gases, forming four volumes, being condensed into two volumes of ammonia. Now it was long known that nitrogen was absolutely necessary to plants, in order to supply them with material for the formation of several vegetable products containing nitrogen, such as albumen, gluten, and fruits and seeds generally. But it was exceedingly difficult to ascertain its true source. There exists now little doubt that its chief source, when not supplied artificially, is in the ammonia of the atmosphere. Minute, therefore, although the quantity of this ingredient be in the air, it has an importance which is very considerable when we know the uses it fulfils. "The quantity of food required by animals," writes Liebig, "for their nourishment, increases, or diminishes, in the same proportion as it contains more or less nitrogen." In other words, that kind of food, as a general rule, is the most nutritious which contains the greatest proportion of nitrogen in its composition. This element, consequently, becomes most essential to the existence of animals; and it is supplied to herbivorous and graminivorous animals

mainly by plants, in the food they derive from the vegetable kingdom. Plants, as we have seen, obtain their nitrogen chiefly from the minute quantity of ammonia contained in the air; and hence it is manifest that the health and vigour, and even the very existence of the whole animal world, is most intimately connected with the presence of a gaseous ingredient of the air, so small in quantity, as to have long escaped the detection of the most accurate experimenters.

Man, it is true, is an omnivorous creature. His food consists of both kinds, animal and vegetable. It may be said, all the nitrogen he requires he can obtain in the greatest abundance from the flesh he consumes as food; and, no doubt, the greater part of those tissues of the human body abounding in nitrogen, such as muscle, &c., are nourished from this source. But the difficulty is only put a step back by this consideration; for we must then inquire from whence do these animals, used as food and themselves feeding exclusively upon plants, obtain their nitrogen? This discovery furnishes us with a sufficient answer,—it is from the vegetable kingdom; and plants derive it in part from the ammonia of the atmosphere. It is thus, by an interesting and beautiful series of links, that this important process, the supply of nitrogen, is carried on. Ammonia, a minute component of the atmosphere, containing the essential element for the animal kingdom, is essential to vegetation; a vegetable diet is essential to the animals we use for food; and a mixed diet is, without doubt, essential to the healthy existence of a man. Thus it is literally true, that a

large portion of our muscles and flesh was once present in the air as a gas.

Many solids are great absorbents of ammonia. Thus, if a piece of freshly-burnt charcoal is put, after cooling, into a glass vessel full of ammonia, and standing over mercury, it will be presently noticed that the mercury rises up into the jar, and a considerable quantity of ammonia has disappeared. The charcoal has undergone no change, neither has the mercury; on what principles, therefore, are we to account for the disappearance of the ammonia? The explanation is to be found in a very peculiar property of gases. By virtue of this property, ammonia, like other gases, is capable of becoming condensed on the surface of bodies, or even liquefied; some possessing a greater aptitude than others for effecting this process. Charcoal, burnt clay, and vegetable mould all possess this property in a high degree, and thus endowed, these substances form appropriate manures.

A recent writer in the Paris Horticultural Review mentions the following curious particulars illustrative of the value of powdered charcoal as a manure:—"About a year ago I made a bargain for a rose-bush of magnificent growth, and full of buds. I waited for them to blow, and expected roses worthy of such a noble plant, and of the praises bestowed upon it by the vendor. At length, when it bloomed, all my

hopes were blasted. The flowers were of a faded colour. I therefore resolved to sacrifice it to some experiments which I had in view. I then covered the earth in the pot in which my rose-bush was about half an inch deep with pulverized charcoal; some days after I was astonished to see the roses, which bloomed, of as fine a lively rose colour as I could wish. When the rose-bush had done flowering I took off the charcoal, and put fresh earth about the roots. You may conceive that I waited for the next spring impatiently to see the result of this experiment. When it bloomed the roses were, as at first, pale and discoloured; but, by applying the charcoal as before, the roses soon resumed their rosy-red colour. I tried the powdered charcoal likewise, in large quantities, upon my petunias, and found that both the white and the violet flowers were equally sensible to its action. It always gave great vigour to the red or violet colours of flowers, and the white petunias became veined with red or violet tints; the violets became covered with irregular spots of a bluish or almost black tint. Many persons who admired them thought that they were new varieties from the seed. Yellow flowers are insensible to the influence of charcoal."

These singular and simple experiments deserve repetition. Since charcoal itself is quite insoluble, its effects are, in all probability, due to the gases it condenses from the air. It must, however, be obvious, that it is highly desirable that experiments of a satisfactory kind, as to extent and character, should be made upon this subject.

It will now be useful to sum up the normal con-

stituents of the atmosphere from the preceding observations. The atmosphere consists primarily of two gases, four-fifths being nitrogen, and one-fifth oxygen; but, in addition, and to adapt it for the purposes of vegetation, and ultimately for the supply of the very existence of animal life, it contains in small proportions varying quantities of watery vapour, carbonic acid and ammonia.

The atmosphere rises above us with its cathedral dome, arching towards the heaven, of which it is the most familiar synonyme and symbol. It floats around us like that grand object which the Apostle John saw in his vision—"a sea of glass like unto crystal." So massive is it, that when it begins to stir, it tosses about great ships like playthings, and sweeps cities and forests like snow-flakes to destruction before it. And yet it is so mobile that we have lived years in it before we can be persuaded it exists at all; and the great bulk of mankind never realize the truth that they are bathed in an ocean of air. Its weight is so enormous that iron shivers before it like glass, yet a soap-ball sails through it with impunity, and the tiniest insect waves it with its wings. It ministers lavishly to all the senses. We touch it not, but it touches us; its warm south wind brings back colour to the pale face of the invalid; its cool west winds refresh the fevered brow, and make the blood mantle in our cheeks; even its north blasts brace into new vigour the hardened children of our rugged clime. The eye is indebted to it for all the magnificence of sunrise, the full brightness of midday, the chastened radiance of the gloaming, and the clouds that cradle

near the setting sun. But for it, the rainbow would want its triumphal arch, and the winds would not send their fleecy messengers on errands round the heavens; the cold ether would not send its snow feathers on the earth, nor would drops of dew gather on the flowers. The kindly rain would never fall, hail-storm nor fog diversify the face of the sky. Our naked globe would turn its tanned, unshadowed, forehead to the sun, and one dreary monotonous blaze of light and heat dazzle and burn up all things.

Were there no atmosphere, the evening sun would in a moment set, and without warning plunge the earth in darkness. But the air keeps in her hand a sheaf of his rays, and lets them slip but slowly through her fingers, so that the shadows of evening gather by degrees, and the flowers have time to bow their heads, and each creature space to find a place of rest, and nestle to repose. In the morning the garish sun would at one bound burst from the bosom of night, and blaze above the horizon; but the air watches for his coming, and sends at first but one little ray to announce his approach, and then another, and by and by a handful; and so, gently draws aside the curtain of night, and slowly lets the light fall on the face of the earth, till our eyelids open, and, like man, she goeth forth again to her labour until the evening.

CHAPTER III.

OCCASIONAL INGREDIENTS OF THE AIR.

AT the extreme end of the valley upon which we are supposed to be looking lies a flat, marshy district, over which in the dewy evenings we may often see suspended a dense cloud of vapour. The whole area of this district is not above three or four square miles, yet its inhabitants are more frequently in ill-health, and the annual proportional mortality is greater there than in any other portion of the plain beneath us. Were we to question them, they would inform us that, when in the hot weather of autumn a current of air blew across the marsh, they might certainly expect attacks of ague to ensue. Their very countenances betray their ill-health, and the long and sallow faces of some are so peculiar, that we may well exclaim, What can be the cause of this unhealthiness? The inhabitants say it is the marsh air. When the same sort of district and effects occur in Italy, the inhabitants attribute it to the *malaria*, or bad air.

No doubt they are correct. The air of such districts contains something in addition to those ingredients which in the last chapter we found to constitute the composition of the atmosphere generally. Nitrogen, oxygen, carbonic acid, watery

vapour, and ammonia, although representing the ordinary ingredients of the atmosphere, are not, therefore, its only constituents in particular cases. The atmosphere may be conceived to contain a little of everything that is capable of assuming the gaseous form: we shall learn, however, further on, that there are active chemical processes taking place in the air itself, which in a short time remove such "occasional ingredients" from its contents.

What is known of malaria at present is insufficient to account for many phenomena. But, from whatever sources, the poison is of a material character; in other words is possessed of weight. This is shown by the fact that it accumulates near the earth, since it is safer to sleep on the top of a house than at the bottom. Persons occupying the lower stories have been attacked with ague, while those on the upper have escaped the complaint. The poison need not be gaseous, for the Italians are in the habit of wearing gauze veils as an efficient protection from it, the infiltered air being thus divested of its injurious powers. It is invisible, inodorous, and gives no indications of its properties, except by its effects.

A very simple experiment will prove the truth of the assertion that a quantity of organic matter is frequently admixed with the air. Thus, it is a property of oil of vitriol to char (blacken) most substances of this kind; now, if a saucer, partly filled with sulphuric acid, is exposed for a short period to such an atmosphere, its colour will, by degrees, deepen till almost black, in consequence of the charring of the organic matter.

We are not speaking of the soot in the air of great cities, which is now so foul a blot as to be destructive of all beauty; this, in itself, is far less injurious to human than to vegetable life. The removal of such a nuisance will probably be an outcome of the introduction of the electric light, as the employment of gas for heating purposes is as yet in its infancy, and will in time take the place of our coal fires.

Again, the various manufactories, the conditions to which the inhabitants are subjected, and the deteriorating influences of man himself, all exert a powerful influence upon the state of purity, or otherwise, of the surrounding air. Dr. Angus Smith, to whom we owe so much, caused a portion of air to be passed continually through a certain quantity of water for three months; he was thus able to detect a certain amount of chemical matter in the air. A part of this was sulphuric acid with some chlorine, and an organic substance resembling albumen. Such matters are constantly being poured into the air, partly from the lungs of men and animals, and from manufacturing processes. On these substances becoming condensed upon cold bodies and in a warm atmosphere, the albuminous matter very soon putrefies and emits disagreeable odours. The oxygen of the atmosphere acts upon it, and it gives rise in its decomposition to carbonic acid, ammonia, sulphuretted hydrogen, and probably other gases. The matter condensing on cold walls in crowded assembly rooms may be collected, by means of a little tube, called a pipette. If allowed to stand it thickens, and on examination under the microscope is found to contain numbers of

minute confervæ, between the stalks of which a number of greenish globules are seen constantly moving about, accompanied by still more minute active particles, presenting a very interesting and beautiful spectacle. If this animal exhalation is allowed to accumulate on various objects, by its frequent condensation on their surface, and subsequent drying up, it forms a gummy organic plaster, which may often be found upon the neglected furniture of dirty houses. In moist weather it decomposes, and produces that peculiarly disagreeable organic smell which no words can describe, but which is only too familiar to our senses in the abodes of misery and poverty. On contrasting this condensed animal exhalation with dew collected in the open air, the most remarkable difference was found to exist. The dew remained beautifully clear and limpid, even when boiled down; the odour was not remarkable; and when the small portion of solid matter which remained dissolved in it was exposed to heat, the smell was that of vegetable matter, with very little trace of any nitrogenized substance. It was also rather agreeable than otherwise.

From these researches it is quite manifest that organic matters are always present in the air of towns. Occasionally, in close, unhealthy neighbourhoods, it may even be perceived by the sense of smell; and that it is not more evident to us when entering a large city from the open country, and fresh air, is due chiefly to the circumstance of our becoming by degrees accustomed to it during the time occupied in our journey. Could a Highlander be suddenly

transported from his heather-covered hills and set in the midst of a densely-populated alley in London, he would instantly be sensible of the existence of a great degree of impurity in his new atmosphere. Persons from the Highlands of Scotland frequently experience this on entering Glasgow, the heat of which produces the same feeling as that of a forge or glass-house; occasionally they are unable to bear its excessive impurities. It has been found that such matters are never absent from the air, and that let it rain ever so much, or long, in a large city, with every shower a quantity of organic ingredients will be brought down. Dr. Angus Smith has even succeeded in determining approximately the amount of these organic impurities of the air. The beautiful violet solution known as "Condy's disinfecting fluid" has the power of oxidizing and destroying many organic substances, becoming itself decolourized thereby. Taking advantage of this property, Dr. Smith ascertained, by experiment, how much of the fluid was decolourized by equal quantities of air drawn from different localities, and found, as might have been expected, that the air of foul rooms and crowded courts decolourized a great deal more than did the fresh country breeze.

These organic substances are, of course, derived from a variety of sources. Some of them are, no doubt, perfectly harmless, while others are of the most deadly description. The sweet vapours from a bed of flowers are organic in their nature, and so are the direful and mysterious *miasmata*, which, with unseen hands, often scatter death throughout a province, or kingdom. We know but little of these terrible

visitants, and cannot judge with certainty of their presence, until the spectres of disease and death which follow them give evidence of it. Yet even in this most difficult and apparently hopeless inquiry, it is encouraging to observe, that the patient labour of many workers has from time to time illuminated the darkness, and given us glimpses of a future filled with hope of better things.

We have noticed the probability, and almost certainty, that the subtile germs of epidemic disease are organized and endowed with life. Pasteur has proved that the germs of plants and animals are always to be found in the organic substance of the air. These bodies are the propagators of fermentation, and can actually be removed by filtration through asbestos, or cotton-wool, or a charcoal respirator of sufficient thickness! When the air is heated to redness every trace of them is removed, although the very act often reveals the presence of organic matter by a smell as of burning; and it has been further proved by Tyndall that mere subsidence may be employed in order to free the air from these germs. Neither milk, nor the juices of meat, nor decoctions of vegetables undergo any change, when the atmosphere has been thus treated. Filtered air is called by Tyndall optically pure. When a ray of light is passed through it no reflection is noticed, because the space, otherwise filled with motes, is empty, and has nothing to reflect the light.

Dr. Beale found, on filtering the air of infected cow-sheds, similar organisms to those which he had discovered in the bodies of the diseased cattle.

Water is a far greater agent of propagation than air. Thus cholera and typhus are communicated by germs, myriads of which are poured out in the excreta of patients suffering from these diseases. Cholera germs, called cholrads by Dr. Farr, are not more than the $\frac{1}{25000}$ of an inch in diameter, and may therefore easily escape all observation except that by the microscope.

One general conclusion is forced upon us by such considerations as the foregoing. It is, that neglect of proper sanitary arrangements is a crime alike in individuals and communities. To use the strong and simple language of the older divines, epidemic disease may be called God's curse on filth. Filth in person and filth in dwelling, filth in air and water and earth, this it is which leads directly to these epidemic scourges. Let it never be forgotten that nearly all epidemic disease is, even in the present imperfect state of our knowledge, preventible by human care; that we have but to drain our lands, ventilate our houses, and keep our water and air pure, and we shall in all human probability cease in a great measure to be visited with these awful maladies. How deeply it is to be wished that these great truths could be brought home to every one throughout the length and breadth of the land! How different might the face of the earth become, if man, who claims to be the lord of it, would but strive to do his duty!

In addition to the presence of organic impurities, that is, impurities derived from animal or vegetable sources, it is certain that impurities of an inorganic kind are often to be met with. A quantity of ammonia sufficient to render rain quite alkaline is occasionally to

be found. The rain which falls in Manchester, owing to the enormous amount of mineral ingredients poured by its immense chimneys into the air, is found to be more charged with mineral matters even, than the water from the neighbouring hills with which the city is now supplied.

Occasionally an adulteration of a more sensible character is infused into the atmosphere, increasing to an enormous extent, and filling the air with haze. A remarkable event of this kind took place in 1782. The phenomenon of which we are about to speak is commonly called "Dry Fog," to distinguish it from the ordinary humid mist called fog. The vast space between Lapland and Africa was shrouded over during the years 1782 and 1783 with a dry fog unequalled in intensity. It was in the form of a pale blue haze, and was so thick at noon-day that the sun looked of a blood-red colour through it. It was not affected by rain, and it extended alike over countries, like our own, of "distempered climate" and others where the air is usually serene and clear. Voyaging was dangerous even in the Mediterranean by reason of it; and it was just as thick on the summit of the highest Alps. Its properties were peculiar. It was said to have a strong disagreeable odour, and that, in some places, a viscid, acrid, liquid had been deposited by it. The greatest alarm prevailed; men's hearts failed them for fear. More terrible visitations were expected. Public prayers were earnestly made to avert the apparently impending doom of all Europe; and such an agitated state of the public mind was probably never known. A tremendous volcanic

eruption in Iceland burnt up seventeen villages, and ejected such a mass of matter as would defy the united efforts of the whole human race to remove, each man taking away as much as he could carry. Awful thunder-storms visited the continent, desolated France, and destroyed a large number of human beings and cattle in England. It was a time of terror, of tumult, and of universal excitement. The summer of 1783 saw at length its termination : violent electric phenomena, with storms of wind and rain, dispersed it, and before the autumn all was gone, the plague was removed. During the whole period that it had lasted, a severe epidemic catarrh—something similar, probably, to influenza—affected men and animals.

These remarkable years were singular as regards "dry fog," principally in the enormous extent of its distribution, a circumstance of which history does not record a parallel example. Dry fogs of a local, or more limited extent, had been before known. Jussieu relates, that "the influenza of the spring of 1733 appeared in France immediately after offensive fogs, more dense than the darkness of Egypt." In the autumn of 1775, in France, influenza appeared with violence, and was ushered in by thick noisome fogs, having been preceded by diseases among the lower animals. About the 7th of October, 1775, Scotland appears to have been visited by the same fog, for we learn that in certain districts a continual dark fog, possessing a particularly smoky smell, made its appearance, and lasted for five weeks. During its continuance the sun could not be seen to shine. During the year that the potato disease was most

extensive in its ravages it was noticed in some parts of the country that clouds of "dry fog" preceded its appearance in some fields.

It has been remarked by some who have sought for the causes of these singular phenomena, that they often occur together with volcanic disturbances. In 1782, besides the tremendous eruption already mentioned, there occurred several earthquakes in Calabria and other symptoms of disquietness in the deep regions of the globe. In the years noted in history for the appearance of dry fogs, in 526, 1721, 1822, and 1834, several volcanoes were in great activity. The meteorologist, M. Kœmtz, reasoning upon this subject, has ascribed the occurrence of the dry fog of 1782 to the enormous volumes of smoke produced by the devastations of the burning lava in Iceland, as it descended on its fiery errand: hence, he conceives, the smoky odour of dry fogs. Several others of these phenomena, he attributes to the smoke emanating from the peat-burnings of Westphalia and Germany.

M. Kœmtz's explanation can scarcely be considered correct. Dry fog is doubtless something more than smoke. When its remarkable accompaniments, volcanic disturbance and severe epidemic attacks, are remembered, it will be evident that some other cause than that specified must be called into account for this phenomenon.

It is difficult to assign to any of the causes alluded to, the existence of a remarkable phenomenon which in November, 1819, alarmed the city of Montreal. On a Sunday morning the whole atmosphere in the city appeared as if covered with a thick haze of a

dingy orange colour, during which rain fell of a thick and dark inky appearance, and apparently impregnated with some black substance like soot. The weather then cleared up, but on the following Tuesday, at twelve o'clock, a heavy damp vapour enveloped the whole city, which was so dense that the inhabitants were compelled to use artificial lights. The appearance was grand in the extreme. About three o'clock a slight shock of an earthquake was felt, accompanied with a noise like the roll of distant artillery. At twenty minutes past three, when the darkness reached its greatest depth, the whole city was instantaneously illuminated by the most vivid flash of lightning ever witnessed at Montreal, immediately followed by a peal of thunder so loud and near as to shake the strongest buildings to their foundations, accompanied by a shower of black rain. Very recently a shower of black rain took place in Ireland, which, together with the alarming phenomenon here described, must evidently have had its origin in the existence in the air of impurities of some anomalous kind.

Occasionally light particles of a more easily explained origin make their appearance in the air. "On the afternoon of June 11, 1847," writes Dr. D. P. Thomson, "the wooded part of Morayshire appeared to smoke, and for a time fears were entertained that the fir plantations were on fire. A smart breeze suddenly got up from the north, and above the wood there appeared to rise about fifty columns of something resembling smoke, which wreathed about like water-spouts. The atmosphere now calmed, and the

mystery was solved; for, what seemed smoke, was in reality the pollen of the woods." Insects, fish, lichens, infusorial animalcules, volcanic ashes, sand, earth, and many other substances are occasionally borne into the air by the action of rapidly revolving currents, and are dropt often at a great distance from the places whence they were snatched.

One of the most remarkable of the ingredients of the atmosphere, present in minute and ever-varying quantities, is the gaseous body discovered by Schönbein, and called by him Ozone. It is an altered condition of oxygen, in which the characteristic properties are greatly intensified.

Ozone, so called from its strong smell, may be commonly identified by the peculiar odour emitted in the working of an electrical machine. However prepared, Andrews has shown that the substance contained in the air agrees in all its properties with ozone. But the very small quantity contained in the atmosphere renders it difficult, at the best of times, to determine the amount. According to some chemists and physicists, the proportion of ozone is dependent upon the amount of atmospheric electricity; according to others, the atmosphere in its normal condition contains a constant quantity.

The method of detection is a very imperfect one, and consists in exposing to the air, papers, which have been soaked in a dilute solution of starch and iodide of potassium; by noting the shade of blue, the amount of ozone is roughly determined. For ozone has the property of oxydizing the potassium in the iodide, and of liberating the iodine, and this latter

with starch forms the blue iodide of starch. Unfortunately, the emanations from certain manufactories produce the same effect upon the test-paper used for the discovery of ozone, and this is especially the case with chlorine, nitric acid, nitrous acid, &c. And, equally unfortunately, the sulphurous acid, which emanates from the numberless chimneys, is instantly oxydized, and converted into sulphuric acid by ozone, and it is in consequence always absent from the atmosphere of crowded cities.

The lately deceased physiologist, Gorup Besanez, successfully traced the formation of ozone in the atmosphere to the evaporation of water, and this is probably its chief source. And now as to its varied properties. In water, ozone is but little soluble, as 1000 measures only take up $4\frac{1}{2}$ measures; the solution has the odour and oxydizing properties of the gas. When dry it may be preserved for a time, but it changes gradually into common oxygen. At a temperature of 458° F., it is instantly changed into oxygen, two volumes of ozone becoming altered into three volumes of oxygen.

As an oxydizing agent, nothing can surpass it. Organic substances of various kinds, paper, caoutchouc, and similar substances are rotted and rendered unserviceable. The colouring matter is removed from blood and its albumen completely oxydized. Many injurious gases, such as sulphuretted hydrogen, and other hydrogen compounds, are rendered harmless. Sulphides become sulphates, phosphorus is at once oxydized to phosphoric acid. Its effect upon mercury is marvellous! One bubble of oxygen, con-

taining only $\frac{1}{60}$ of its bulk of ozone, robs several pounds of mercury of its lustre and convexity.

At the sea-side ozone is frequently perceived by the smell, and doubtless is a sign of purity of atmosphere, as it cannot exist in presence of organic filth, whether only in decay, or in putrefaction.

We have already pointed out that ozone is but a modified form of oxygen, and it has never been separated in a pure state. The utmost that we can obtain is a mixture of pure oxygen with a small proportion of ozone. When such a mixture is exposed to the action of mercury, the mercury takes oxygen from the ozone, though it is unable to do so from common oxygen, and the ozone is destroyed. In some beautiful experiments, which were published in the "Philosophical Transactions" for 1860, Dr. Andrews and Mr. Tait ascertained the effect produced upon a certain volume of oxygen by its partial conversion into ozone, and the subsequent absorption of this ozone by mercury. They found that during the formation of ozone, the gas contracted, 100 measures of oxygen yielding, in an extreme case, about 92 volumes of "ozonized oxygen." It was therefore evident that ozone was heavier than oxygen, bulk for bulk. They then proceeded to absorb the ozone by means of mercury, naturally expecting by this means to ascertain the volume which it occupied. But, to their great surprise, they found that after the whole of the ozone had been removed, the remaining oxygen had precisely the same volume which it had while mixed with ozone, so that the latter appeared to occupy no space at all! This very curious and apparently

anomalous fact was soon explained by Dr. Odling. It is admitted by nearly all modern chemists that each of the ultimate particles, or molecules, as they are called, of oxygen, really consist of two atoms, incapable of a separate existence. Dr. Odling pointed out, that all the facts received a simple explanation, on the assumption, that the molecule of ozone contained three, instead of two, atoms of oxygen. The reason, he said, why oxygen contracts during its con version into ozone is, that three atoms become con densed into the space formerly occupied by two; and the reason why mercury produces no alteration in the volume of ozonized oxygen is, that the metal only absorbs one of these three atoms, the remaining two atoms occupying the same volume as the three.

This hypothesis has since been confirmed by a striking experiment made by M. Soret, in which it was found that, when the ozonized oxygen was exposed to the action of oil of turpentine, instead of mercury, a contraction of volume was produced; oil of turpentine having the power of absorbing the whole molecule—all three of the atoms—of ozone.

There is one satisfactory test for ozone, in that the test-paper above-mentioned, after ozone has done its work of liberating iodine, turns red litmus paper blue, owing to the presence of the potash; this action is impossible on the part of any of the agents which might also separate iodine from the iodide of potassium.

There is another ingredient of the atmosphere which may almost be regarded as one of its essential constituents. This is nitric acid. When a series of

electric sparks are passed through dry air, the nitrogen and oxygen unite to nitrogen peroxide; but if moisture be present, nitric acid is formed. Therefore, every flash of lightning which darts through the air causes, along its line, a minute portion of nitrogen, oxygen and water, to unite to nitric acid. It is very soluble in water, and often occasions rain to exhibit acid properties, especially in tropical climates. On an average, about 2 lbs. of nitric acid are said to fall upon each acre of ground. It is very favourable to growth, and affords to plants a supply of nitrogen, which they seem almost only capable of obtaining from ammonia and from nitric acid.

When nitrogenous organic matter is exposed to the air, ammonia results: this is a combination of nitrogen, with hydrogen. But when lime, potash, or soda are met with in the soil, the nitrogen is oxydized to nitric acid, which then forms nitrates of lime, potash, or soda. Now the nitrates are as favourable to vegetation, as is nitric acid.

So, then, we see, that the decay of vegetable and animal bodies gives rise to certain emanations, which may occasionally contaminate the air. This is the case with sulphuretted hydrogen, perceptible by its odour, like unto that of rotten eggs. It is often emitted from sewers and drains, and has been known to turn the lead, of white-lead paint, into black sulphide of lead in one night. One of the advantages of zinc-white, when used as a paint, is, that it does not darken in such an atmosphere, as sulphide of zinc is white. For the same reason, vermilion, which is a sulphide of mercury, is preferred to red-lead, or to chromate of lead,

as a paint for letter-boxes, because the sulphuretted hydrogen of the drains can have no effect upon a body which is already a sulphide.

There can be little doubt that the oxygen and ozone of the atmosphere are capable of changing the form and removing most occasional ingredients of the air, and that these are the best disinfectants. But the most injurious occasional ingredients are probably solid, nitrogenized, and endowed with vitality. Sulphuretted hydrogen is injurious, and, even in small quantities, lowers the general standard of health, but cannot give rise to epidemic diseases.

When decomposition sets in, the tissues of the animal frame become resolved into gaseous matter and water. The atmosphere seizes again upon these, and takes quickly from them their capacity for doing mischief. Such as may be beneficial in their relation to created beings, are simply taken up and distributed far and wide for the service of creation. There is a singular gradation observable in this process of decomposition, which well deserves our attention. The process of destruction is slow, and advances from one step to another. The air attacking a compound of complex constitution, reduces it to one of more simple nature, and so on, until the simplest is arrived at, and this is innocuous. The change is at length complete; the body is literally dissolved either into gas, or water; its fluids and solids are dispersed, and the bleaching bones and earthy materials of the skeleton alone remain, to indicate that the framework of an active and animated being had once rested on the earth.

A singular exception to the general rule of the decomposition of the body after death exists, as we are told by Mr. Willis, in the bodies of those who are deposited in the vaults of St. Michan's church in Dublin. These vaults are perfectly dry, and are occupied with the remains of bodies which have been deposited there for centuries. From a published account of these vaults we make the following extracts:—"The bodies of those long departed appear in all their awful solitariness, at full length, the coffins having mouldered to pieces! but from those, and even the more recently entombed, not the least cadaverous smell is discernible, and all the bodies exhibit a similar appearance, being dry, and of a dark colour. The floor, walls, and atmosphere of the vaults of St. Michan's are perfectly dry, the flooring is even covered with dust, and the walls are composed of a stone which is peculiarly calculated to resist moisture. This combination of circumstances contributes to aid Nature in rendering the atmosphere of these gloomy regions more dry than the atmosphere we enjoy. In one vault are shown the remains of a man who died at the advanced age of one hundred and eleven; the body has now been thirty years in this mansion of death, and although there is scarcely a remnant of the coffin, the body is as completely preserved as if it had been embalmed, with the exception of the hair."

The durability of animal and vegetable substances in Upper Egypt, in consequence of the peculiar dryness of the air, is quite extraordinary. In the most ancient tombs are to be found sarcophagi,

chests, chairs, tools, and other things made of wood, grains of corn, dried fruits, almonds, dates, nuts and grapes, plaited reeds, papyrus and a number of linen articles, all in a state of perfect preservation. Mummies that have lain there for centuries have been discovered with the hair, skin, and features entire.

Hence we learn, that though accidental impurities undoubtedly find a temporary lodgment in the air, they instantly, if of a kind admitting decomposition by oxygen, begin to alter, and if of an unchangeable kind, they are at no distant period removed from it. Thus the Chemistry of nature, rightly interpreted, teaches us that the atmosphere is not only the grand receptacle, but also the laboratory for the decomposition of a large number of the constituents of the animal and vegetable frame, and of such other ingredients of a foreign kind as find their way into it. All organized bodies part with a majority of the elements which compose them into this great reservoir, mainly in the form of the compounds carbonic acid, water, and ammonia, but not therefore to be irrecoverably lost. The atmosphere is a faithful conservatory for these constituents. They may be scattered to the four corners of heaven, but they shall reach their proper destination in the end. The watery vapour, the carbonic acid, and the ammonia would seem to be lost; but in process of time they must return again, and take their allotted place in the operations of the universe. The oxygen of the air, combining with carbon in the organs of animals, is returned to the atmosphere as carbonic acid gas. This gas is decomposed by plants, which restore the

oxygen to the atmosphere, assimilating the carbon. The same changes take place in the sea and in fresh water. Thus a perpetual balance of animal and vegetable life is constantly maintained; and we have succeeded in imitating this, on a small scale, in that beautiful contrivance the aquarium. Millions of animals may die, leaving their putrefying carcasses to rot in the wilderness, or in the jungle, or in the depths of the caves of the earth; and it might be thought that all the valuable constructive materials which entered into their composition were for ever removed from usefulness. But it is not so. Every wind that sweeps over these remains, bears away the volatile portions round about the world. The gentle rain comes down and washes the soluble parts away, supplying a fertilizing fluid to the roots of distant plants. The interchange of ingredients never ceases. Millions of animals feed upon the vegetation nourished by the decay of former myriads. Their time is then completed; their period of utility is ended: they die. The air again receives their elements, and again with continually succeeding generations do these enter into activity in the economy of the world.

The grand truth of the indestructibility of matter has been happily enunciated by Shakspeare, and aptly put into the mouth of the philosophic Hamlet:—

"HAMLET. To what base uses we may return, Horatio! Why may not imagination trace the noble dust of Alexander, till he find it stopping a bung-hole?

"HORATIO. 'Twere to consider too curiously to consider so.

"HAMLET. No, faith, not a jot; but to follow him thither

with modesty enough, and likelihood to lead it. As thus: Alexander died, Alexander was buried, Alexander returneth into dust; the dust is earth; of earth we make loam; and why of that loam, whereto he was converted, might they not stop a beer-barrel?

"Imperial Cæsar, dead, and turn'd to clay,
Might stop a hole to keep the wind away.
Oh! that that earth, which kept the world in awe,
Should patch a wall t'expel the winter's flaw."

Hamlet, act v. scene ii.

CHAPTER IV.

THE WATERS OF THE AIR.

"GREAT IS OUR LORD AND OF GREAT POWER: HIS UNDERSTANDING IS INFINITE." "SING PRAISE UPON THE HARP UNTO OUR GOD, WHO COVERETH THE HEAVEN WITH CLOUDS, AND PREPARETH RAIN FOR THE EARTH, WHO MAKETH GRASS TO GROW UPON THE MOUNTAINS." "HE GIVETH SNOW LIKE WOOL; HE SCATTERETH THE HOAR-FROST LIKE ASHES. HE CASTETH FORTH HIS ICE LIKE MORSELS: WHO CAN STAND BEFORE HIS COLD? HE SENDETH OUT HIS WORD, AND MELTETH THEM: HE CAUSETH HIS WIND TO BLOW, AND THE WATERS FLOW."—Ps. cxlvii.

"MY DOCTRINE SHALL DROP AS THE RAIN, MY SPEECH SHALL DISTIL AS THE DEW, AS THE SMALL RAIN UPON THE TENDER HERB, AND AS THE SHOWERS UPON THE GRASS."—Deut. xxxii. 2.

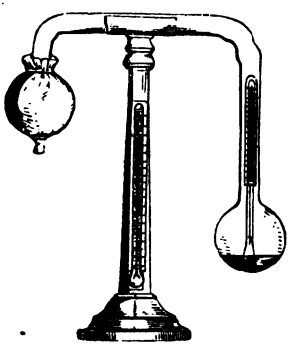
IN all the various forms assumed by this beautifully constituted fluid, as dew, mist, rain, hail, and snow, we are presented with remarkable illustrations of the importance of such an ingredient in our air, and of the wisdom of that great and glorious Being who employs the simplest means to accomplish the greatest amount and variety of beneficial results. No one questions the fact, that the rivers, lakes, seas, and oceans are the great reservoirs of water for the use of the globe; but few remember, that not only is the atmosphere a reservoir of water also, but that it

is the chief medium through which, on the large scale, the contents of the rivers and seas become available for the necessities of the land. Such is, however, perhaps as important a function of the air as any that has been assigned to it;—an office, the cessation of which would render the earth waterless, would dry up our rivers, and confine both animal and vegetable life to the immediate vicinity of the sea-shore.

We can easily prove the existence of water in a gaseous form in the air. On putting a few lumps of ice into a tumbler, the surface of which is carefully wiped clean, and carrying the glass into a sitting-room, it will be immediately found to be covered with a dense cloud of dew, which will form again and again, even after the first deposit has been wiped off. The amount present in the air varies greatly, but a certain portion is never absent, and the amount is usually greater in warm than in cold air. It arises from the evaporation of water on the earth. The atmosphere, on the summit of lofty mountains, is occasionally remarkable for the absence of watery vapour. On the lofty passes of the Cordilleras this degree of dryness produces some curious effects. Articles of food become perfectly dry and hard; wood-work shrinks; and if a mule dies, it is preserved from putrefaction, as this process, in the absence of water and germs, does not take place for a length of time. The atmosphere in such a condition is remarkably clear and transparent. Electricity also is developed on the slightest friction; articles of flannel clothing, when rubbed in the dark, glisten with the electric fire, and the hairy coats of animals crackle and emit sparks.

The state in which watery vapour exists in the air is closely analogous to that of the other gases, and it is influenced equally with them, within certain limits, by the laws of diffusion. There is, however, this great distinction, that watery vapour is liable to become condensed and liquefied at common temperatures. Carbonic acid gas, like all other gases, can be liquefied, but only under the influence of cold and extreme pressure. Watery vapour, on the contrary, is readily made to assume the liquid condition. When this takes place, that is, when the vapour passes from the vaporous into the liquid state, the phenomenon called "dew" is produced. The philosophical explanation of the formation of dew is simple. There exists for watery vapour a state of density which it cannot pass without losing its gaseous condition and becoming liquid. This state is conveniently expressed by the term, "the maximum density" of the vapour. The point on the thermometer at which watery vapour attains its maximum density is dependent upon the temperature of the air, increasing as the temperature increases, and sinking as the temperature falls. Consequently, if the temperature of the evening were 50°, the point of the maximum density of watery vapour would be lower, and the facility with which it would be deposited in the liquid form, as dew, would be greater than if the temperature were 70°. Now, when any substance, or surface, becomes cooled down, whether naturally or artificially, to a little below the point of maximum density of watery vapour, the latter immediately loses the form of vapour, and becomes condensed in minute drops

upon the cold surface; the point at which this takes place is called the "Dew-point." The late Professor Daniell invented an interesting little instrument, of considerable importance in hygrometric pursuits, entitled the "Dew-point hygrometer." It consists of a bent glass tube, terminating in two bulbs, one of which is half filled with ether, the whole being vacuous as respects atmospheric air. In the ether bulb is a delicate thermometer; a piece of muslin wetted with ether covers the empty bulb outside. The cold produced by the evaporation of this ether condenses the ether vapour inside the tube, and rapidly lowers the temperature of the ether bulb until dew appears on its surface. When this takes place, by looking at the little thermometer inside, the dew-point is easily read off.



DANIELL'S HYGROMETER.

In nature, the deposition of dew takes place under the following circumstances:—The atmosphere always contains an uncertain amount of water, in the shape of vapour. Now the quantity of watery vapour which the air can hold in solution is dependent upon temperature; the higher the temperature, the more vapour it contains. So soon as the sun sinks beneath the horizon, the earth, no longer absorbing the rays of heat from that source, begins rapidly to lose, by

radiation, its temperature acquired during the day. This cooling process continues, until the surface of the ground and the bed of air overlying it, has reached the dew-point, and then most objects become covered with a deposit of pearly dew. Those substances which in the air become cool first, must also attract, first and most abundantly, the particles of falling dew. Thus, in the cool of the summer's evening, the grass-plot is wet, while the gravel-path is dry; and the thirsty pasture and every green leaf are drinking in the descending moisture, while the barren highway is unconscious of its fall.

So also it has been found by gardeners that a slight screen will effectually preserve their plants from severe cold, the radiation of heat being in this simple manner effectually prevented. The natives of Peru, too, having observed that it only freezes when the sky is clear, contrive to create artificial clouds, whenever, from the appearance of the sky, they apprehend a frost. This they do by setting fire to heaps of damp straw, which raise clouds of smoke over their crops.

Dew is pure water containing a minute trace of ammonia. If we liken the bedewed surfaces to the condenser of a still, we see more of the force of the Scriptural expression: "My speech shall distil as the dew."

> "Those verdant hills now bathed in morning dews
> Whose every drop outvies Golconda's gems,
> Lo! one hangs glittering on that blade of grass;
> Spurn not that lucid trembler, but admire
> Its glorious hues, and trace them to their source
> The nice arrangement of its particles.

Draw nigh;—through microscopic lens inspect
That single drop's profound elaborateness—
Most delicate and wonderfully wrought.
Is it a work of chance? It is a world
Replete with life, and love and joy. Its crowds
Dart swift from verge to verge (their ocean depths).
How nervous and minute each supple fin!
What made that film-like hinge on which it plays?
What hand, what eye, save God's could fashion it?"

Every poet worthy of the name has sung the praises of the dew.

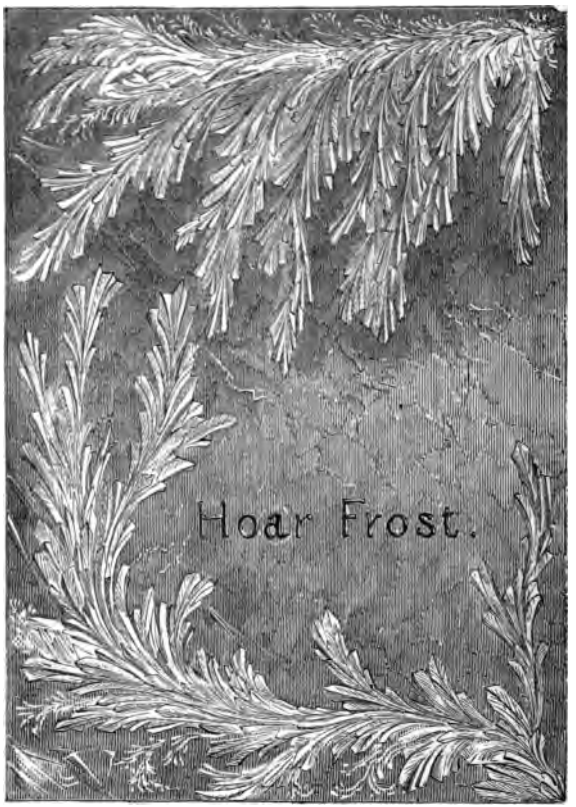
"I must go seek some dew-drops here,
And hang a pearl in every cowslip's ear,"

says our own Shakspeare, and it would be easy to fill a book with its praise and yet not go one whit beyond the truth. But we have more to say.

If the earth continues to lose heat by radiation, even after the formation of dew, it may be reduced as low as 32°, the freezing-point, or even lower. The dew then freezes, its limpid particles become set fast in solid beads and crystals of various forms; thus *hoar-frost* is produced. The extraordinary beauty of the crystallizations thus formed must have been universally perceived.

There is something eminently interesting in noticing the occasional glimpses of an adjusting principle which we may catch in a survey of the kingdom of nature. The deposition of dew is an illustration in point. The heaviest dews, other circumstances being favourable, succeed the hottest, clearest, and driest days. Hence the dew is most abundant when it is most necessary. In hot climates the dews are most

profuse; and the morning sun rises in its strength upon a landscape which the gentle hand of night



has cooled, refreshed, and invigorated with a sea of dew-drops. Thus, though no rain-carrying cloud

may cross the blue air during the day, to shed its supplies of refreshing waters upon a parched earth, the clear and brilliant evenings witness, in the phenomenon we have been considering, a grateful and efficient compensation; and the thirsty vegetation, satisfied with its evening portions, is enabled without injury to endure the rays of the burning luminary all the day long.

Dew, in common with all water shed upon the ground, has important duties to fulfil. Besides quenching the thirst of plants, dew is instrumental in facilitating the distribution of some interesting substances. Thus, a certain amount of moisture is almost essential to the escape of odour from many bodies. Much of that pleasure which we ourselves derive from the perfume of plants, depends on the assistance to its vaporization rendered by dew. "Who," writes the late Professor Fownes, "does not inhale with rapture the perfumes of a flower-garden, when the dews of night, or the refreshing summer shower, have awakened the thousand sweet odours of its fair inhabitants? The breath of the hawthorn and of the rose have been always one of the most favourite themes of the poet's song; and yet, this endless succession of pure and simple pleasures, is but a mere consequence of the law which bids a vapour, arising by its own elasticity from a volatile substance, mingle itself with the surrounding air, and extend its influence until its effects become so enfeebled by dilution, as to be imperceptible to the sense." The presence of moisture also favours the escape of disagreeable odours, as may be noticed in

damp weather, and especially with a change of temperature. But it will be asked how it happens that water becomes thus dissipated and lost in air? By the wayside, some time ago, was a pool some 6 or 12 inches deep,—a place for ducks to sport in and for cattle to drink. Where is it now? The parched, cracked mud at its bottom is all laid bare. It is certain that it has not sunk into the earth, for the subsoil is a heavy clay; it has all become dissipated into the air in the form of vapour: in other words, it has *evaporated*. A saucer full of water placed on a sunny window-sill becomes emptied by this invisible force before night.

It is found that water and all liquids evaporate, or pass off invisibly into the air, even at low temperatures, there being a fixed amount of water which the air is capable of taking up for each given temperature. Ice evaporates in the open air, even when the temperature is below the freezing-point. This process goes on, until the vapour has attained, what has been before called, its maximum density; evaporation then ceases, and if its temperature becomes suddenly lowered, the vapour condenses into the form of a liquid. When a drop of water, spilled on a slab, disappears, it does so because it is able to pass into the invisible condition of a vapour, in spite of the pressure of the air on its surface. The water has as much the power to resolve itself into fine particles, which elude our notice, as if no air were present.

It has already been mentioned that watery vapour is never absent from the air. When, owing to some reduction of temperature, this vapour passes its point

of greatest density, it becomes visible to the eye in the form of a mist, or fog. The cause of a fog would then seem to be the intermingling of a warm with a cold current of air, each charged with watery vapour: upon both thus mingling together, so great a reduction of temperature in the warmer current takes place, that its excess of moisture is immediately rendered visible as fog and is rapidly deposited.

Clouds are nothing more than masses of mist in the higher regions of the air, when considered in their merely scientific aspect. All that exquisite and inexhaustible variety of effect, which the artist loves to imitate and the eye to rest upon, all those glowing pictures of mansions in the skies, of fantastic landscapes, of fleecy snowdrifts, of overhanging mountains and rocks gilded by a declining sun, are the results of the play of light upon a mass of little particles of water.

"Was I deceived, or did a sable cloud turn forth her silver lining on the night?" says Milton.

"Those playful fancies of the mighty sky!"

"A summer-cloud, that looked as though an angel, in his upward flight, had left his mantle floating in mid-air."

"Bright clouds, motionless pillars of the brazen heaven, their bases on the mountains—their white tops shining in the far ether—fire the air with a reflected radiance and make turn the gazer's eye away."

There are three great and characteristic forms of cloud, the cirrus, cumulus, and stratus.

The lightest of clouds, that therefore which ascends to the greatest heights, and is seen at almost all seasons of the year is the cirrus. From its height it

is often lighted up by the rays of the rising or setting sun, while the lower clouds are in darkness. It lies in patches on the deep-blue sky, while its motion is generally slow, and its appearance fibrous, delicate, and thread-like.

The cumulus is the cloud of spring and summer. Formed in the day-time, its density keeps from the earth the sultry rays of the noon-day sun. Towards evening it gradually disappears, owing to the increased temperature of the superior strata of air. Its form, when viewed sideways, increases from above in dense convex heaps; in hot weather it often appears stationary, with a flattened base, its rock-like summits showing with a silvery light. When the cumulus increases after sunset and shines with a ruddy hue, it indicates the coming of a thunderstorm.

The stratus is the horizontal sheet of cloud nearest to the ground: it occurs chiefly at night, or in the cool of a calm evening. It frequently appears on fine autumnal mornings and evenings, sometimes resting on the ground, sometimes hovering a few feet above it. The stratus deposits moisture which is often cooled into hoar-frost, rendering the face of nature exquisitely beautiful: it is also the occasion of mists which are scattered by the rising sun. It is most frequently seen from September to January.

There are also several well-defined modifications of the three forms of cloud already described, to be recognised in cloud-land.

The cirro-stratus, like the cirrus, is to be found in the higher cloud-region, and is to be seen at all seasons. Sometimes it appears dark and threatening,

at others, attenuated. The cirro-stratus accompanies a fall in the barometer, and is the precursor of wind and rain.

The cirro-cumulus is often formed from the cirrus: it is the warm-weather cloud and attends a rising barometer. When seen alone in the higher regions of the atmosphere, it assumes a dappled appearance and is commonly known as a mackerel-back sky. More frequently it bears the form of small round patches of cloud, leaving between them openings of clear blue sky. The glorious crimson contrasting with the delicate blue of a fine sunset, and the rich golden hues pervading the bright blue of a sunrise in summer, are due to the cirrus and cirro-cumulus.

The cumulo-stratus is the most dense form of cloud, and causes, in passing, a sensible reduction of temperature: it is made up of the cumulus, the cirro-cumulus, and the cirro-stratus. It forms the thunder-cloud and indicates changes of wind, hail and storm.

The nimbus is a modification of the cumulo-stratus cloud, seen in profile during a shower, and is never seen with a high barometer: its attendant is the rainbow. Scud is like stratus, of the clouds nearest to the earth. It is common in the winter-months, and is seen most frequently after rain.

The clouds may further be divided into two groups, the first comprising cirrus, cirro-stratus, cirro-cumulus, and scud, which descend and produce rain and wind. The second, including stratus and cumulus, which ascend, and are the attendants of fine weather.

However considered, the phenomena of clouds are such as to fill us with wonder. Held up mysteriously

in the air, their ample folds retain and convey to parched lands at a distance, or to regions of high mountains and cliffs, thousands of tons of the refreshing draught. Laden with fresh-distilled liquid, at first perfectly soft and free from mineral matters, and borne upon the wings of the broad wind, they descend, water and make fertile the earth, softening it and making the green pasture to sing for joy.

Although it is not difficult to assign the ultimate cause of rain to a change of temperature, or to define the process by which vapour becomes rain, it must be confessed that great obscurity still rests upon the laws which influence its occurrence, and upon the actual nature of the phenomenon. Rain occasionally falls from a sky clear as crystal, and altogether undimmed by a cloud. Such a phenomenon does not appear to have been often noticed in our own country; but an observer, who was at Constantinople, relates that he was out in a pretty heavy shower which lasted for ten minutes, while the sky was serene and cloudless. In the island of Mauritius, this phenomenon is very common, in the seasons when the south-east winds blow. About evening time, while the weather is most beautiful, and the stars shine with the utmost brilliancy of lustre, a very fine rain occasionally descends; and Sir J. C. Ross relates that in the South Atlantic, it rained upon one occasion for upwards of an hour, while the sky was altogether free from clouds.

The wet season of tropical countries, a season of almost unintermittent rain of the heaviest kind, is a very remarkable and regular phenomenon, but is

explicable on simple principles. At such periods the atmospheric currents, which in these countries are of great steadiness and duration, receive an altered direction, and the condensation of an enormous volume of watery vapour, and its precipitation in the form of rain, take place as a result of the accompanying intermixture of hot and cold streams of air.

Important chemical functions are discharged by rain. There are regions where, for five or six months in the year not a drop of rain falls, and a cloud is scarcely ever seen on the clear sky, yet many trees preserve all their beauty and freshness of aspect. We are not, however, therefore to suppose that the office of rain to vegetation is either trifling, or unimportant. In these peculiar circumstances it has been suggested that the appendages of the stem, or the leaves themselves, are gifted with a peculiar function of withdrawing watery vapour from the air, and thus sustaining existence when it would otherwise be impracticable. But it must also not be forgotten that the soil itself has the property, in a remarkable manner, of absorbing watery vapour from the air, and no soil possesses this property more remarkably than that which is formed of decayed vegetable tissues, and other matters called humus. Hence, in the tropics, where such a soil is rapidly produced, plants do not suffer as much as might be the case in time of drought, were the soil not possessed of this property. It would, indeed, appear from some observations and calculations of Dr. Schleiden, that the greater part of the water used by plants does not

come from rain, but from the vapour silently condensed by the soil from the air.

Large supplies of fluids are drawn by the delicate spongioles of the roots from the earth and transmitted to the stems. The water thus obtained enters into the circulation of the plant and undergoes decomposition to meet its wants, while the excess flies off through the stomata (mouths) of the leaves, or escapes, laden with scent, from the cells of the flower.

As the medium by which a number of soluble substances of importance to the well-being of plants are conveyed to them, the importance of rain to the vegetable economy appears still more evident. Falling in the manner described, rain is in the most favourable condition for dissolving any ingredients of a soluble kind present in the air through which it passes. Its minute state of division, and the consequent exposure of a vast amount of surface to the soluble matters, or gases present in the air, renders it a most efficient and valuable medium for bringing down the hoarded treasures of the air to the needy and expectant soil. When the chemist, in his manipulations, wishes to obtain a saturated solution of a gas, he effects it by a process as nearly as possible similar to that by which in nature the same result is produced; he violently agitates the liquid so as to reduce it to a mass of drops, exposed on all sides to the gas intended to be dissolved. Where machines intended to charge water with gases, and partly to dissolve the latter in the water, as in the manufacture of soda water, are employed, the same effect is pro-

duced by a revolving agitator driven at such a speed as to beat the water into a fine mist. Now, M. Schubler has calculated that upon a field of 26,910 square feet, the annual fall of rain is about 2,520,000 lb. In this large amount of rain-water is contained much ammonia, on the lowest calculation about 80 lb. All this ammonia existed previously in a gaseous form in the air, having been brought down in a dissolved state by rain, and in this simple but beautiful manner is rendered available to vegetation; to which, had it remained in the gaseous form, it would otherwise have been of little use.

Carbonic acid gas also is soluble in water, and exists in air in still larger and less variable proportions than ammonia. If the rain dissolves the one, it must dissolve the other gas, and the two unite together to form carbonate of ammonia. This solution, coming in contact with the roots of plants, is absorbed by them, conveyed into the digestive organs of the vegetable economy, and being decomposed there, contributes towards the formation of the solid portions of the vegetable structure. Rain-water, when freshly fallen, also contains relatively a larger proportion of oxygen than does the air.

But the beneficial duties of rain, to vegetation, do not end here. When the emigrants of a new colony set about clearing whole forest districts, and destroy by burning the timber they cannot store, or transport, there are found in the ashes large quantities of alkalies and other mineral ingredients. These once existed in the structures of the trees, particularly in

the leaves and young branches, and rain was the chief instrument by which they were introduced. Being produced in the soil by virtue of processes which have already come under notice, they assume a soluble form, become dissolved in the rain-water as it trickles down from the surface to the roots, and are then absorbed and appropriated by the spongioles of the plant. It is curious that a shower thus produces a stream of water, actually containing more salts and earthy matter, than the water which trickles through the ground. Rain, by softening the ground, renders the matters therein contained more soluble. The frosts of winter break up the ground, and the succeeding rains of spring supply the roots of plants with an abundance of soluble matter, then so important to them.

As a mere mechanical agency, rain is also of great service to plants. Any one who has seen the accumulation of dust and dirt which the traffic on roads and the manufacturing and other operations carried on in towns cause to be deposited on all vegetation within their reach, and has again noticed the fresh and cheerful aspect of the vegetable creation when a new-fallen shower has been succeeded by a clear sky, will perceive the importance of this function also to the well-being of vegetation. The particles of dirt thus deposited, if not removed by some means, would most seriously interfere with the respiration of the plants. The stomata or mouths of the leaves would become clogged up and unfitted for the discharge of their peculiar functions, and the most injurious consequences to the health of the plant would ensue.

But the shower comes down, and in a few minutes all is clean again; every function is restored to its due activity, and the scene assumes a freshness of colouring quite peculiar to such seasons. The remark does not seem to have been previously made, but, it may be suggested: is not the glossy coating of evergreen shrubs intended to facilitate this process, rendered all the more necessary by the length of time the leaves endure?

As it restores cleanliness and freshness of garb to the vegetable world, so rain also exercises a most beneficial influence upon the condition of the atmosphere. It carries with it the mass of carbonaceous particles which, owing to the bad construction of our fireplaces, are cast forth into the air. It also brings down that invisible, though not always inodorous, cloud of organic matters which floats in the atmosphere of populous places, and very probably renders in many cases these otherwise dangerous ingredients of the air of towns comparatively innocuous. In fact, it may very reasonably be doubted whether our large towns would be able to exhibit such low rates of mortality as many of them in average seasons do, were it not for the frequent heavy showers, the occurrence of which too often forms the subject of complaint against our unstable climate. The rain which falls through the smoke-filled air of our towns contains a large quantity of soot in suspension, not in solution. Dust comes down with the purest rain, consisting chiefly of coal-ashes, which are apparently the source of the sulphates and chlorides found in rain. It is sometimes acid with sulphuric acid.

Though, doubtless, the presence of these matters in the atmosphere is in a lesser degree injurious to human respiration, it is far more so to vegetable life; for neither the most healthy previous condition, nor the most careful tending, will preserve plants in perfect health in our large cities.

Let us follow the rain-drops in their descent to the earth. Whatever soluble matter is met with by the rain, at the surface of the soil, it carries with it as it sinks downward into the earth. All the unpleasant products of organic decay on the surface, that are soluble, are conveyed downwards by it, and the water thus polluted sinks to the underground reservoirs, from whence man draws his supply of this indispensable fluid. What results might we not therefore anticipate on an examination of water drawn from such receptacles; and what a polluted condition might we not expect the soil to be in, which forms the filter through which this decaying organic matter penetrates! It is surprising that organic matters, properly so called, are scarcely, in reality, found in these wells; and, more singular still, the wells nearest to a source of organic matter, frequently contain less than others, farther removed from the apparent probability of contamination.

This seems highly paradoxical, but it admits of being very beautifully and simply explained. The analysis of the waters of the wells in towns shows that they contain a quantity of nitrates. Even a water of such excellence as that of the Kent Company contains nitrates, and this is the result of the oxydation of nitrogenous matters. But it is not the quantity so

much, as the source, of the nitrates which requires looking into, and it warns against the accumulation of refuse near the sources of drinking water.

There is, however, an active process of oxydation constantly occurring in the soil, and this is greatly promoted if the soil is porous and contains such oxides as lime. Thus a natural filtration is accomplished, the fulfilment of which is intimately connected with the health and well-being of man. The suspended matters in waters are generally the most injurious, and this is certainly the case when waters contain the contagion of cholera, typhus, &c., consequently the most complete filtration is to be recommended to those who would guard effectively against sickness.

Just as filtration promotes the oxydation of organic matters, so also does the mere rapid flow of water bring about a similar result. It may require a flow of several miles before this is accomplished, but the conclusion is sure.

When the rain-drops in their course towards the earth are exposed to a degree of temperature below freezing-point, or 32° of Fahrenheit's thermometer, they become congealed into solid masses, and in this condition are known as hail. It has been considered by some that hail is produced by the rapid descent of the rain-drops when first formed, causing a rapid superficial evaporation, the cold produced by which freezes the rest of the globule. Hail is also produced from a nucleus of snow, which gathers weight as it descends. As the frozen drop falls, condensing continually more watery vapour around it, which, becoming also frozen, adds to its size, it proceeds with

accelerated rapidity until it reaches the earth, striking on its surface frequently with considerable violence. It is supposed by others that the origin of hail is attributable to the sudden encounter of two masses of cloud of very unequal temperature. Hailstones of a very large size are frequently found in summer hail-storms; and the force with which they fall is proportionate to their size. Hailstones of the size of a goose's egg have occasionally been picked up in the Orkneys. It has been calculated, that the rapidity with which hailstones of a large size fall, equals fifty miles an hour, their destructive force being correspondingly great. The mischief done by hail at times can scarcely be estimated. Many thousands of pounds would not cover the damage of the tremendous hail-storm of 1846; and in vine countries their ruinous effects are felt still more severely. Seasons are on record when the whole vintage of large domains in Southern France, and elsewhere have been annihilated. On the 14th of January, 1849, at a certain town in the Deccan in India, there was a hail-storm, during which some of the stones were from two, to two and a-half inches in diameter, and weighed from one to two ounces each. Hailstones present various crystalline appearances on examination. A hail-storm is frequently accompanied by violent electrical phenomena.

Snow is formed under circumstances corresponding to those accompanying the formation of rain, but instead of condensing into drops, it crystallizes, from a previously vaporous form, into a multitude of minute separate forms, often possessing the greatest variety

and singularity of appearance. After undergoing this change of condition, the snow begins gradually to descend, forming in its course small flakes, which, uniting with others in fantastic groups, at last reach the earth. Elegant varieties of form are frequently discoverable in the structure of a snow-flake even in our own temperate regions, but in the arctic regions they occur more abundantly, and their forms would seem to be more varied and fantastic. The celebrated arctic traveller, Scoresby, has described a great number of different crystalline forms: some of these forms are represented in the adjoining cut. Strange to think, a few degrees less heat evolve these beauties of form and aspect out of a drop of water! Strange also to remember, that a few degrees more heat reduce them all to the transparent mobile fluid out of which they sprang! It has been supposed that snow favourably influences vegetation, from its containing a solution of atmospheric oxygen; but, most probably, the non-conducting properties of snow, by preventing the dangers of excessive cold to plants, are those to which its serviceable reputation is chiefly due.

There can be no doubt now that electricity plays a most important part in these aqueous phenomena of the atmosphere. Humboldt writes—"In fogs, and at the beginning of falls of snow, I have, in the course of a long series of observations, seen the previous permanently vitreous" (positive) "electricity, change suddenly into the resinous" (negative) "electricity; and these alternate repeatedly, as well in the plains of the frigid zone as under the tropics in the Paramos, or Alpine wilderness of the Cordilleras,

between 10 and 12,000 ft. high. The alternate transition was in all respects similar to that, which the

CRYSTALS OF SNOW.

electrometer had shown shortly before, during the continuance of a thunderstorm."

All the explanations hitherto offered of the cause of rain are incomplete, but the production of rain hail, and snow is greatly influenced by electricity.

Propositions have been made for bringing down artificial rains. It is well known that the Indians of Paraguay, when their crops are threatened by drought, adopt the expedient of setting fire to vast plains of grass, and as the result expect rain and even thunderstorms: nor are they often disappointed.

PRAIRIE ON FIRE.

A similar effect has been also observed to follow the occasional conflagrations which take place in the American prairies and woods. It is conceivable that in these cases great electrical disturbances are oc-

casioned, which end in the production of rain. It has been noticed at Manchester, that the weather has become constantly and progressively more and more rainy as the city has increased in size, and in the number of its vast manufactories; so that now the number of rainy days is very large indeed. M. Arago, the French astronomer, appears disposed to account for this singular fact by supposing that the enormous chimneys of the cotton mills and other factories, withdraw a large amount of electricity from the atmosphere, and thus bring about this effect. The effects of volcanoes, in producing rain by their eruptions, are sometimes very remarkable. It has been related, that when a volcano bursts out in South America during a dry season, it not unfrequently changes it to a wet one. Great fires in different localities have been said to be often followed by violent rain, with thunder and lightning.

CHAPTER V.

MOVEMENTS OF THE AIR.

"MOTION IS THE LIFE OF ALL THINGS."

UPON the blue horizon of the scene we are contemplating, something resembling a white cloud may be seen gently gliding along the distant waters. By the aid of a telescope we make out this white object to be a vessel under sail. In a little time it is lost to view; it appeared to sink into the vacancy between the water-edge of the horizon and the sky which it almost seemed to touch. Turning our eyes towards the sky, we perceive the light and fleecy clouds, borne smoothly and slowly along. The smoke of a cottage chimney beneath us does not rise straight into the air, but is slightly bent to one side, and stretches out slantingly upwards for some distance. The browsing of a sheep hard by has shaken a full ripe thistle—

> "A whitening shower of vegetable down
> Amusive floats"—

and is carried silently and smoothly over the field, until it is lost to sight.

All these phenomena indicate movements in the air, although, where we are now placed, they are so soft and gentle that we do not feel them. But some

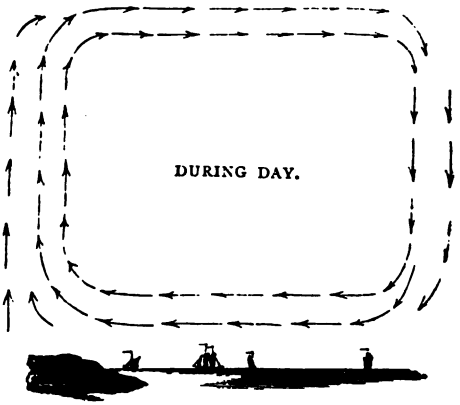
of the movements may be actually seen. If we look attentively at certain objects, as on a hillock, upon which the heat of the sun has been directed all day long, we shall perceive a number of minute undulations in the air just above it. This is rendered still more apparent if a telescope is employed, and it so interferes with the direction of the rays of light, as to make the objects appear distorted and indistinct. Upon the sea-shore this effect is sometimes curiously manifested, and at a little distance off we may observe the whole shore-line marked by the waving and trembling stratum of air rising above it up to a certain height. The cause of these tremulous movements is undoubtedly the heat of the sun, since on a cold, or cloudy day they are not perceptible. The grand cause, indeed, of most of the movements of the air is the solar ray, and the mode in which it acts is explicable in a simple manner.

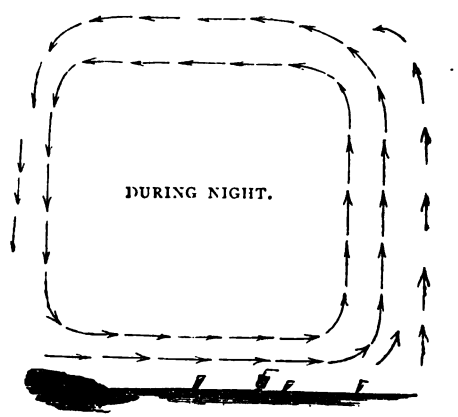
It is generally said that the air only receives heat from its contact with the earth, and absorbs but a very minute portion of the heat-rays of the sunbeam as they pass through it. Recent experiments have shown this idea to be in some measure erroneous. The watery vapour present in the air absorbs these rays in a remarkable degree. "Regarding the earth," says Tyndal, "as a source of heat, no doubt at least 10 per cent. of its heat is intercepted within ten feet of the surface." We are thus shaded, as it were, at all times from the full influence of the solar heat. While, however, this is true, it is also certain that the atmosphere receives a much larger portion of heat from its contact with the heated earth. In

consequence of this the particles of air expand, become specifically lighter, and are rendered sufficiently buoyant to rise upwards, their places being immediately supplied by cooler particles of air drawn from the vicinity. If, therefore, we suppose a particular spot, or tract of land, to be heated by the sun, while a neighbouring part remains comparatively cool, the immediate result is that an upward current rises from that spot, and ascends into the higher regions of the air. But, as it rises, its place below must be occupied by an equal bulk of air, which is necessarily derived from the sides. A current is thus immediately established, an ascending stream in the one case, and a horizontal flow of greater, or less force in the other.

It is stated by an authority, that if on a still day, the atmosphere of London, or some other great city, were to be carefully observed in calm weather, it would be found, that in the morning, streams of fresh air are flowing in from the country round about the metropolis down all its suburban streets, to supply the place of the current which, heated by the vast city, rises up into the air from its centre: Prevailing currents, or other accidental circumstances, so constantly interfere with this phenomenon, as to make it difficult to verify the observation. A common fireplace furnishes us with an excellent home illustration of the same laws. A hot ascending current pours up through the chimney, and to take its place a cold horizontal stream sets from under the door, or from openings in the floor made for this purpose. In tropical climates this law produces the interesting

and vastly-important natural phenomenon of Land and Sea breezes. During the day, under the powerful rays of a vertical sun, the land becomes greatly





heated and much more so than the sea; an ascending current consequently arises from the land, and to supply the place thus partially vacated, a body of cool air flows in from seaward, producing the sensible effect of a fresh breeze blowing from the sea, from about nine in the morning, until two or three o'clock in the afternoon. The sun then beginning to lose its power, the land also begins to cool, and towards evening, and during the night, the land being a better radiator of heat than the water, it becomes colder than the sea. The heated column, therefore, now rises from the sea, and the cold horizontal flow is from the land, the sensible result being a fresh breeze to seawards. When the heated column in either case reaches a certain height in the air, it turns over, blows along the upper regions, and then comes down to supply the place of the descending current. This will be readily understood by reference to the figures, which rudely represent the state of things during the day and at night.

A modification of the same phenomena which has been frequently observed in mountainous regions, is the hill and valley breeze, and it arises precisely from the same cause, namely, inequality of temperature setting in motion an ascending and compensating current. Mr. Darwin makes particular mention of a powerful one observed by him in his travels in Mexico.

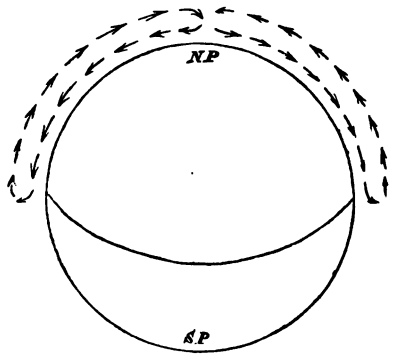
Winds due to a similar cause, whose periodical occurrence was familiar to the ancients under the title of the Etesian winds, take place on land, when one district being more heated by the solar rays than

another, the cold current of air flows from and across others, to supply the place of the ascending hot current.

Incomparably the most important and grandest atmospheric movement is that of the Trade Winds; and we shall find in this phenomenon, another illustration, on the large scale, of the fact of inequality of temperature producing movements in large masses of air. There are particular regions of the globe whose temperature is in the most violent contrast, as those of the equator and the poles. Here, therefore, we have all the conditions necessary for the production of motion in the air. Under the beams of a tropical sun, the equatorial regions become heated to a high degree, and over a vast area. The result is, that an enormous body of air rises from these regions, the place of which must be supplied from cooler parts. Hence, if the earth were not in revolution on its own axis, a cold current would flow from both poles directly to the equator, there rise with the ascending heated current, and turning over, it would proceed to the poles in the higher strata, and would again descend to pursue the same course. This is clearly indicated in the accompanying diagram.

But the earth revolves on its axis. In so doing it carries its atmosphere with it. The equatorial regions being further from the central axis of the earth, are in more rapid motion than the polar, just as the rim of a wheel moves faster in the same time than any part of the axle, and therefore the equatorial atmosphere has a more rapid movement through space than that of the poles. If now we suppose a

current to be dragged across the surface of the earth, from the slowly revolving poles to the rapidly revolving surface of the equator, it is neces-



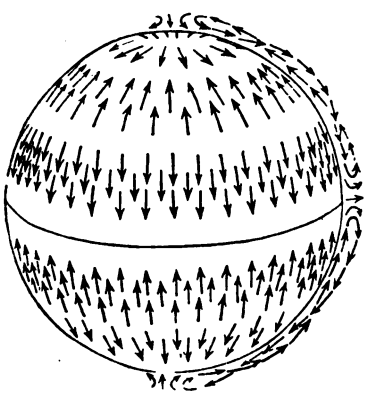
sarily unable to proceed at once at the same rate as the latter, and the consequence is, that the swiftly moving regions of the earth *brush* against a mass of air having a slower motion than themselves. Hence there are two forces to be considered in the production of the trade winds—1st, the ascent of a heated equatorial column of air, and 2nd, the resistance offered by a slowly moving current of air proceeding in a horizontal direction from the poles to the equator. If the earth were stationary, the under current would perpetually blow directly from the poles to the equator; but, in consequence of its revolution, the direction of the current is bent aside, and the wind becomes an easterly wind with a direction from the north, or from the south in south latitude, instead of a strictly north or south

wind. Since the earth revolves from west to east, a current of air, having a less velocity than the surface over which it was being drawn, would be felt by one standing on the earth as a wind from the east. As we approach the equator its northerly direction gradually ceases, and it is felt as an east wind, and thus forms the more proper trade wind, a current blowing from east to west within the tropics. Thus the high temperature of the equator sets in motion, and the revolution of the globe modifies, the direction of the trade winds.

The effect of the earth's motion in producing what is felt to be a wind, by its brushing against a body of slowly moving air, may be rendered somewhat more intelligible by reference to an every-day illustration. A traveller on a railway engine, going at the rate of thirty or forty miles an hour, experiences apparently a very powerful current of air blowing in his face. Yet he may notice the distant smoke curling up from the cottage chimney, and rising into the air in an almost perpendicular column; the leaves on the tall poplars beyond are still, and the few fleecy clouds which rest on the blue sky have no sensible motion. The atmosphere, then, is calm and motionless. The apparent wind is the result of the resistance a swiftly moving body experiences in passing through the air. The current is, in fact, the difference between the motion of the carriage and that of the air through which it passes. In like manner, the mariner sailing on the watery surface of our swiftly rotating globe is whirled along, insensibly to himself, at a greater velocity than the bed of air which lies above him, and

the sensible effect is, that he perceives a strong and equable wind in the opposite direction.

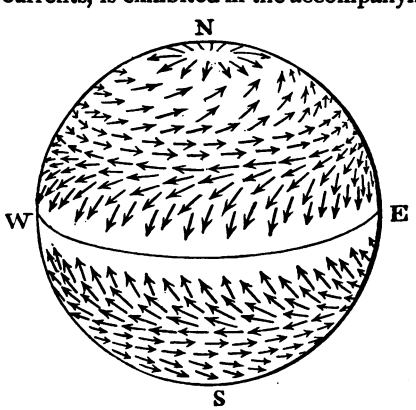
Having thus hastily traced the lower current to the equator, let us now follow the ascending column. Upon rising to a certain altitude, it is there to some extent cooled, by parting with its heat into space, by radiation, and its upward progress is necessarily arrested; the current is then deflected, and flows towards the poles in a grand stream. As it proceeds it still loses heat, and at about the 30th degree of latitude, it is so cold as to descend and change places with the lower current from the poles. Proceeding onwards still, it receives heat from its contact with the earth, and again rises to form the upper current,



being displaced by the cold and heavy air flowing from the poles. There is thus a sort of atmospheric chain formed, which will be more clearly understood by reference to the cut. At all places, however,

above the latitude of 30°, in consequence of the variations in the amount of heat received from the earth, these currents are very irregular.

Now, this upper current, having a different velocity, in consequence of its origin at the swiftly rotating equator, to that of the more northerly or southerly slower-moving regions which it has now reached, takes on the apparent character of a wind from west to east, and thus appears as a westerly wind. And when the upper current descends to take the place of the lower, at about the 30th degree of latitude, it is actually felt as a violent westerly gale. At the poles, and within the polar circles, there is a constant, steady, polar gale towards the equator on every side. The effect of the earth's motion, in altering the direction of these currents, is exhibited in the accompanying cut.



The upper current was long suspected to exist, before its existence was positively known. Professor

Dove, in his "Witterungs Verhältsnisse von Berlin," cites the following instance: "On the night of April 30th, explosions like those of heavy artillery were heard at Barbadoes, so that the garrison at Fort St. Anne remained all night under arms. On May 1st, at daybreak, the eastern portion of the horizon appeared clear, while the rest of the firmament was covered by a black cloud, which soon extended to the east, quenched by the light there, and at length produced a darkness so dense that the windows in the rooms could not be discerned. A shower of ashes descended, under which the tree branches bent and broke. Whence came these ashes? From the direction of the wind, we should infer that they came from the Peak of the Azores; they came, however, from the volcano Morne Garou in St. Vincent, which lies about 100 miles west of Barbadoes. The ashes had been cast into the current of the upper trade. A second example of the same kind occurred on January 20th, 1835. On the 24th and 25th, the sun was darkened in Jamaica, by a shower of fine ashes which had been discharged from the mountain Coseguina, distant 800 miles. The people learned in this way that the explosions previously heard were not those of artillery. These ashes could only have been carried by the upper current, as Jamaica lies north-east from the mountain. The same eruption gives also a beautiful proof that the ascending air-current divides itself above, for ashes fell upon the ship Conway, in the Pacific, at a distance of 700 miles south-west of Coseguina. Even on the highest summits of the Andes, no traveller has, as yet, reached the upper

trade. From this some notion may be formed of the force of the explosions; they were indeed tremendous in both instances. The roaring of Coseguina was heard at San Salvador, a distance of 1,000 miles. Union, a sea-port on the west coast of Conchagua, was in absolute darkness for forty-three hours; as light began to dawn, it was observed that the sea-shore had advanced 800 feet upon the ocean, through the mass of ashes which had fallen. The eruption of Morne Garou forms the last link of a chain of vast volcanic actions. In June and July, 1811, near St. Miguel, one of the Azores, the island of Sabrina rose, accompanied by smoke and flame, from the bottom of a sea 150 feet deep, and attained a height of 300 feet, and a circumference of a mile. The small Antilles were afterwards shaken, and subsequently the valleys of the Mississippi, Arkansas, and Ohio. But the elastic forces found no vent; they sought one, then, on the north coast of Columbia. March 26th began as a day of extraordinary heat in Caraccas; the air was clear and the firmament cloudless. It was Green Thursday, and a regiment of troops of the line stood under arms in the barracks of the quarter San Carlos, ready to join in the procession. The people streamed to the churches. A loud subterranean thunder was heard, and immediately afterwards followed an earthquake shock, so violent that the church of Alta Gracia, 150 feet in height, borne by pillars 15 feet thick, formed a heap of crushed rubbish not more than six feet high. In the evening the almost full moon looked down with mild lustre upon the ruins of the town, under which lay the crushed bodies

of upwards of 10,000 of its inhabitants. But even here there was no exit granted to the elastic forces underneath. Finally, on April 27, they succeeded in opening once more the crater of Morne Garou, which had been closed for a century; and the earth, for a distance equal to that from Vesuvius to Paris, rang with the thunder-shout of the liberated prisoner."

A variety of local winds, receiving their peculiar modifications from the circumstances in which they originate, are to be found treated of in works upon meteorology. Many of these, together with those here mentioned, appear to be easily explained upon the great principle of the inequalities of temperature. But many circumstances render it at least probable that other causes of motion in air exist besides those of heat and cold.

It will also be readily conceded that alterations in respect of the electricity of the air may have some direct or indirect influence in setting in motion irregular currents of air.

One of the most remarkable and beneficial discoveries hitherto made by meteorological science is what is called the rotatory theory of storms. By this is meant the remarkable fact that hurricanes, typhoons, and it is probable other violent storms in all regions of the world, have a revolving motion. They do not blow, that is to say, in a straight line from a point many hundreds of miles distant, but they are vast eddies in the air, which whirl round like the eddies of a stream of water, or like the water let out of a basin by a plug at the bottom. Besides this revolving

movement, these storms have also a movement from place to place, and it is highly remarkable that this movement of translation also takes place in a curved direction.

The connection between the movements of the air and the Chemistry of nature is most intimate. The irregular capricious winds which constantly agitate the air of temperate regions, fulfil a most important office in Nature's chemistries. Powerful as is the influence of the diffusive force of gases in dispersing abroad the noxious emanations of any particular district or region, it may be reasonably doubted whether this force is anything like sufficient of itself to preserve the purity of a densely-populated region. It is true we might not be sensible of any ill effects from even a three days' calm in our own temperate climate, although such a state of the air seldom endures for more than a few hours. But this could not long continue without originating very serious evils. If we imagine a crowd of human beings placed in a hall, however great its magnitude, and the air of such a building entirely without motion, it is easy to foresee the result. The impure emanations from the lungs and bodies of so many human beings would accumulate in this motionless mass of air to such an extent as to render it, in a lesser, or greater period of time, altogether irrespirable, and death would be the consequence of continuing under its influence.

Such also would be the condition of a great city over whose hundreds of thousands of inhabitants hung an atmosphere totally without motion, without a breeze to fan the cheek or a storm to intermix the

various parts of air and impurities together. Under such circumstances a city were as surely doomed to destruction as though the windows of heaven were opened, and her living multitudes engulfed in a deluge of waters.

It is, however, impossible for such a condition as a dead calm to exist in the atmosphere of any region. It is true that to the senses there may be no apparent motion in the air, and every leaf of the forest may hang idly and unstirred on the branches. But there are invisible movements incessantly occurring in the stillest air. Not only by day, but even in the stillness of night these insensible commotions are constantly taking place. Not only in the open air, but in the closest shut apartment, the airy particles are never at rest. This is easily proved. Let the windows be closed up with shutters all but a little hole through which a pencil of sunlight may stream. Standing at a little distance, we may perceive that the whole track of the sunbeam is as it were animated. Particles of dust are seen incessantly rising, falling, moving now in this, now in that direction, thus plainly indicating that the air in which they float is moved without ceasing.

A part of these insensible and imperceptible motions of the air are due to its elasticity, and to the facility with which its particles, like those of all gases, move over or between each other, at the application of the least force. If we do but gently breathe upon the thick and numberless particles forming

"The gay motes that people the sunbeams,"

they are instantly thrown into the most violent com

motion, and the disturbance does not cease, in consequence of the small amount of friction, for a very long period.

Much also is due to the effect of heat upon air. A body heated, whether naturally or artificially, instantly causes motion in the particles of air by which it is surrounded. If, for example, a cannon-ball were heated to redness and placed on a tripod, as in the cut, it would cause the surrounding air to be in rapid motion. A stream of hot air, upon the principles before alluded to, would rise up, and a stream of colder air would be continually called to occupy its place. In this manner a current would be set up which would somewhat resemble, could its direction be rendered visible, the appearance shown in the cut. Therefore every object upon which the sun shines, every tree, rock, and hill before us, that feels the genial influence of its rays, is an instrument for communicating motion to the air, and, in a degree by no means to be despised, assisting to preserve the intermixture and purity of the atmosphere.

The effect of these imperceptible movements is perhaps slight for a given time, but in their constant operation, at times when no breath of air stirs around us, they contribute largely to preserve the air of our apartments and cities in a condition fit for respiration,

or at least more fit by far than if they did not exist. When we reflect how soon by their agency and that of diffusion a cloud of smoke is dispersed, until not a trace remains; how soon an offensive gas is wafted away, or a volume of dust dispersed, we shall be better able to appreciate this unseen instrumentality.

Proportionately to its increased force is the purifying influence of wind. The last-named movements are able to dissipate impurities only to a small extent, and within a very limited area. Wind, on the contrary, is a body of air in movement sufficiently powerful to sweep away every accumulation of foreign ingredients in the atmosphere generated by accident, or by the influence of congregated masses of mankind. How often do we, who live in temperate latitudes, vainly and thoughtlessly bemoan the inconstancy of the wind. But, in all probability, were there a constant current from any quarter, it would not accomplish anything like the amount of intermixture which is effected by the shifting winds of which we complain. These capricious currents carry away the smoke of cities and roll the masses of aërial impurities hither and thither, until they become diluted indefinitely and ultimately entirely lost. Again they return, bearing from the fields and woodlands the pure air—

> "Gently attempered and disposed so well
> That still it breathes forth sweet spirit and
> wholesome smell."—SPENSER.

Thus by their ceaseless changes they so agitate and

intermingle the atmosphere as to preserve in it a degree of purity and freshness not otherwise attainable.

It will be necessary, in a future page, to advert to the use of the trade-winds in carrying forward and preserving the purity of the atmosphere as a whole, and some sort of equilibrium of temperature. The tropics are thus the perpetual sources of enormous floods of warm air, which, rising up and flowing over, proceed ultimately to the poles and exert a very considerable modifying influence over the severity of the arctic regions, as well as over those which they traverse on their way.

How beautiful is the unity and dependence of creation! The movement of even a breath of air is not purposeless, although we may not always be able to follow it to its destined end.

CHAPTER VI.

THE ATMOSPHERE IN ITS RELATION TO ANIMALS.

CONSIDERING that all animate and inanimate bodies alike are immersed in a sea of gaseous fluids, which possess affinities of a powerful kind for the different elements of the organic and inorganic kingdoms, it will not surprise the reader to learn that important chemical functions are perpetually discharged by the balmy and apparently inert air which fans his brow, or cools his cheek. To these chemical relations of the air we are now to draw attention, and in so doing we shall first direct consideration to the Chemistry of one of the most important functions of the animal frame—namely, the function of breathing, or respiration.

When we expire the air we had previously taken into the lungs—no matter whether from the mountain ridge or from the less healthful atmosphere of a crowded town—an important alteration in its chemical composition has taken place. We are not conscious of this fact; but it is one which may be readily proved by the simplest means. If a vessel is filled with water in which some fresh-burnt lime has been slaked, and the water decanted off clear—which is now what is commonly called lime-water—and if then, taking a glass tube, we breathe some of the air we are expir-

ing from the lungs through it, we shall have rapid evidence that a change of some kind has taken place in this air in the altered appearance of the previously clear and pellucid fluid. It now becomes quickly turbid and milky, and eventually deposits a whitish sediment. Air, in its ordinary condition, would not produce this change, except to a very trifling extent, whatever it may be; for the liquid remains comparatively unclouded, though a large volume of air be passed through it by a bellows. Therefore the air we take into the lungs has this striking difference from that we expire from them, that while the former produces but little alteration in lime-water, the latter quickly renders it turbid. It will be interesting now to inquire—What is the nature of this difference?

The white precipitate is carbonate of lime, an earth formed by the union of carbonic acid gas with lime. From analyses already given of the composition of the atmosphere, carbonic acid has been found to be invariably present in air, and therefore it might be said this precipitate indicates nothing more than what might have been expected. And it is true that in lime-water, exposed for any length of time to the air, carbonate of lime is formed, and falls to the

bottom of the vessel. But in the simple experiments above mentioned this difficulty disappears, for it will be found that the bellows must be moved for some time to get a sensible precipitation, whereas one or two expirations of air from the lungs will render the fluid quite turbid. Although, therefore, it is certain that a minute portion of carbonic acid exists in all air, it is, on the other hand, equally certain that there is an enormous disproportion in the quantities contained in ordinary and in expired air. In the one the amount is merely fractional; in the other it is present to a large percentage. The air in doing duty in the lungs, while it loses oxygen, receives a large amount of carbonic acid gas.

Let us now enter upon another range of thought. If a *vein* be opened, and some of the blood circulating in the system be thus withdrawn, the fluid thus derived is always of a dark colour, and sometimes almost black. But, occasionally, disease calls for the opening of an artery, and then the most striking difference is perceptible in the appearance of the blood, for it is of a vivid bright scarlet hue. If the dark venous blood is exposed for some little time to the fresh air, it loses its dark colour, and assumes the lighter aspect of arterial blood: but it still differs from arterial blood in many important particulars. This change is directly attributable to the influence of air, for it would not take place in a vacuum. If a moist piece of bladder were laid over the fluid, it would not prevent the change from dark to red; and it is known to physiologists, that when dark blood becomes circulated in an organized living structure

over a large surface, upon which alternate currents of fresh air play, the mere circumstance that air is not brought into direct contact with blood does not interfere with its chemical effects on that fluid. Direct contact with air is therefore not necessary to effect the change, since it will take place very readily through the medium of an interposed animal membrane. This is, in part, due to the laws of the interpenetration, or diffusion of gases, and, in part, to the remarkable power of passing through moist membranes which gases in solution possess in common with many other liquids.

The requisite conditions, then, for the chemical changes of respiration to take place between the air and the blood are, access of fresh air, and the circulation of dark blood on one side of a moist animal membrane. In the lungs these conditions exist to their fullest degree. There, perpetual influxes of fresh air play upon an enormous surface of animal membrane, which is covered with a dense mesh of blood-vessels, all carrying dark blood. To these organs the streams of blood from the remotest parts of the body are directed by the propulsive energies of the heart. At the same time, muscular arrangements in the external and internal walls of the chest, and kept in action by an untiring power, continually partly fill and empty these organs, which are subdivided into innumerable tubes, terminated by minute cells, producing the ordinary phenomena of inspiration and expiration, or, in other words, of breathing. By this means, a measured quantity of air is admitted to the chest, and then expelled again, and so on alter-

nately, about eighteen times in each minute. The pure air is thus received, and the impure is discharged.

At this stage, two facts about respiration are brought prominently under our view:—1st. There is a discharge of carbonic acid gas from the lungs.—2nd. In the lungs, a remarkable alteration takes place in the blood. And we must proceed immediately to add to them a third, of nearly equal importance; namely, that while carbonic acid gas is discharged from the lungs, a quantity of the oxygen of the inspired air is received by them, and disappears in the process of respiration. Thus, to put the changes in clear terms, from the measure of air which goes into the lungs, a certain measure of oxygen is abstracted, the place of which is supplied by the addition of carbonic acid: it is however found that more oxygen is removed from the inspired air than is replaced in combination with carbon as carbonic acid. We are naturally, therefore, led to suppose that these three chemical phenomena—the change of the blood, the absorption of oxygen, and the discharge of carbonic acid gas in respiration—are in some measure connected with each other. Their connection is as follows:—

The blood—in circulating along the arteries, through the fine capillary vessels, to the veins which carry it back to the heart, and in the performance of its various duties, as the source of nutrient and regenerative matter, to every portion of the animal frame—besides parting with many other ingredients, in furnishing the various raw materials necessary for the

animal fabric and its various functions, loses a large amount of oxygen, which, in its condition as arterial blood, it had previously contained. In so doing, it acquires carbonic acid and other principles, which would be quickly fatal to life did they remain and accumulate in it, and it changes colour from the bright scarlet to the dark hue. In short, from being "arterial" it becomes "venous" blood. Blood upon which this change has passed may now be considered as unfit to fulfil the functions previously devolving upon it. To render it again serviceable for the purposes of the animal economy, it must be altered, and restored to the pure and healthful state of arterial blood. It is a well-known fact, that venous blood cannot circulate for any length of time without producing the most serious and even fatal consequences. Some chemical agency, therefore, must interfere to restore its lost wholesomeness, or the functions of the animal economy would soon cease, never to be recommenced. After performing its round, the blood is directed into the lungs, and poured through millions of fine tubes which line the walls of the air-cells. Here the blood comes into contact with the air inhaled into these organs. Exposed on such a vast surface to atmospheric influence, the dark fluid loses the carbonic acid with which it is laden, as well as much watery vapour and other waste-products, and it receives from the air a fresh supply of oxygen; it now turns from dark-red to scarlet, and from the deleterious character of venous to the healthful composition of arterial blood. This done, it is quickly removed from the lungs by means of several large

blood-vessels, singularly straight and simple, and re-enters the heart, which, by its incessant toilings, despatches it on its life-giving errand throughout the frame.

Warm-blooded animals exhale nitrogen in proportion of from $\frac{1}{100}$ to $\frac{1}{80}$ of the oxygen consumed in breathing; yet when the same animals are partially or wholly deprived of food, as during hybernation, an absorption of nitrogen usually occurs.

It is evident that these beautiful arrangements are designed to facilitate oxidation, the formation of carbonic acid and the loss of oxygen being clearly due to the oxidation of carbon, or carbon-containing compounds, within the body. The mechanism by which this oxidation is effected has been studied with great care by physiologists, and although some parts of it still remain obscure, very interesting light has been thrown upon the subject. If we examine a drop of blood through a microscope, we find that it consists of a clear yellow liquid, in which float myriads of red discs, like biscuits in shape. They are so minute that eight millions of them might be packed in the compass of a pin's head, and so numerous, that the tiny drop of blood drawn from the finger by the prick of a needle may contain five millions of them. We are powerless to conceive such numbers, but an idea may perhaps be derived from the calculation that a room sixty feet long, thirty feet wide, and fifteen feet high, could not contain as many grains of corn as there are discs in a single teaspoonful of human blood!

The whole of the colour of the blood is due to a

definite chemical compound contained in these discs; it has the curious power of combining with oxygen, holding it in a loose state of combination, and subsequently giving it up again to substances which are capable of becoming oxidized. The discs thus act as carriers between the oxygen of the air and the compound destined for oxidation. In venous blood they are nearly free from loosely-combined oxygen, and are then purple in colour. During the passage of the blood through the lungs they absorb oxygen, and then become scarlet. When the blood starts from the heart in its race through the body, it is therefore stored with oxygen, which lies in loose combination in the discs. During the whole of the circulation this oxygen is given out—in small doses, as it were—the blood discs pass gradually back to the de-oxidized, or venous condition, and then return to the lungs to take up a new supply of oxygen.

The precise seat of the oxidation is still a matter of some uncertainty, but many considerations make it probable that the oxygen of the discs is partly given up to substances present in the blood-vessels, but that the chief oxidation takes place outside of their walls. "The blood which is the life thereof" penetrates to the innermost recesses of the body, to every organ and every tissue. It carries the nourishment which these organs and tissues require, and it conveys from them the products of their constant waste and decay.

Let us now put the following inquiry:—If a thermometer were placed under the tongue of an Arctic seaman, and the degree marked by the instrument compared with that indicated by another placed in

the mouth of a Hindoo, or any other inhabitant of the burning tropics, would there be any difference between the two points? In the one case, an icy air, seventy or eighty degrees below the temperature natural to the body, would surround the individual; in the other, a scorching heat, many degrees above that temperature, might envelop him. Yet, notwithstanding this extreme degree of contrast in external circumstances, there would be actually no difference, or but a very trifling one, between the degree of heat indicated in each case!

This wonderful truth informs us of two things—1st, that the animal frame has an internal source of heat, in the main unaffected by external cold; and, 2nd, that it has a power of refrigeration, or of reducing its temperature, by which it is enabled to prevent its natural temperature rising beyond a certain point. The latter function, upon which we shall not further dilate, is due to the cold produced by the enormous evaporation which takes place from the surface of the body, and to the direct loss of heat by radiation. The former and more mysterious power is known to physiologists under the title Animal Heat, and to this we must briefly advert.

It is found that whenever the element carbon undergoes, in any of its combinations, the process of oxidation or union with oxygen, the change is invariably accompanied by the evolution of more or less heat. It is no matter where the combustible material is burnt, that is, is united with oxygen; whether in a furnace of iron, or in the animal frame, the same quantity will give out the same amount of heat.

Reasoning upon this fact, physiologists have come to the conclusion that the organs of the body are its heat-furnaces, and that processes of oxidation occurring in them produce just as much heat as would fuel if burnt in a fire-place or consumed in a lamp.

It has been proved, that in the liver, kidneys, lungs, and other organs of the body, chemical and physical changes are continually taking place. Chemistry positively assures us that this cannot occur out of the body without the extrication of heat; we may infer that a similar effect is produced in the body.

Again, the animal frame possesses other sources of heat, in addition to that of respiration, derived from the processes of oxidation. For instance, every movement in the body, whether voluntary or involuntary, produces heat.

The carbonic acid given out in respiration is a sufficient proof that carbon has been burnt somewhere, for when carbon burns in air it forms carbonic acid gas, and the above consideration indicates the locality where this heat-producing process takes place. Respiration is really and truly a process of combustion. The chief fuel consumed is the carbon and hydrogen contained in the materials of the blood; and therefore derived, indirectly, or immediately, as the case may be, from the food. Calculations have been made as to the actual amount of fuel necessary to keep up the temperature of the human body for one day, and it appears, that of all economical furnaces the animal frame is that which evolves the most heat from the same amount of fuel;

for an adult healthy man only consumes for the purposes of respiration about fourteen ounces of fuel-carbon every day. No artificial furnace can indeed compare with these animal furnaces, for the most economical consumes, according to Liebig, not less than from ten to twenty times this amount of fuel in producing the same amount of heat. A large quantity of hydrogen, also, is consumed in respiration, and produces a notable amount of that sum of heat, which, with the thermometer at 'Temperate,' is required to keep the body at 96° or 97° for one day.

The function of respiration, therefore, alone makes large demands upon the body for fuel. Man supplies this, together with the other demands for his nutrition, &c., by the food he consumes. A large part of the food is fuel. Just as in winter we find it necessary to heap up our fires, and thereby to increase the consumption of fuel in order to keep up the temperature of our dwelling-houses to an agreeable point, so with man. In proportion to the intensity of external cold must be the amount and heat-giving quality of the food he requires. Food differs largely in the amount of heat equal quantities will give out. Bodies into whose composition carbon and hydrogen enter largely, are those whose combustion will afford the most heat. He who basks in the heated air of the Tropics requires but little combustible food, compared with him who is condemned to the rigours of a polar atmosphere. Hence the easily-satisfied Hindoo might conceive it utterly impossible for an Esquimaux, or a Russian, to devour his seven or eight pounds of flesh *per diem*, with the addition

of train oil and tallow candles! Yet, if he were placed in similar external circumstances, he would probably find his appetite so sharpened as to compel him to adopt a somewhat similar habit of life. The great amount of heat lost by radiation and conduction from the body of the Esquimaux must be made up, or life will be forfeited. Respiration can make up a great part of it, but it requires a proportionate supply of heat-giving fuel, and it is a familiar fact, that oils and fatty matters are substances which in their combustion eliminate a very large amount of heat in consequence of the large proportion of carbon and hydrogen entering into their composition. We must not, however, suppose that all the enormous quantity of extra food consumed by an inhabitant of the Polar regions is burnt in the lungs, in order to supply heat to the body. Far from it! Calculations have been made which show that, if such were the case, the individual must inhale eight times as much oxygen as an ordinary adult, and his pulse must move at the rate of 500 beats a minute. This is clearly impossible, thus indicating that by far the greater portion of the heat of the body is produced in other organs.

The appetite in a healthy man is the beautifully-adjusted measure by which the fuel-food requisite for the condition in which he is placed is determined. In the keen air of the north it is much more loud in its calls, than in the heated and depressing atmosphere of the Equator; and a careful attention to this natural index would enable men, in these contrasted situations, to regulate their supply of food accordingly;

and would doubtless tend in some degree to the preservation of health of body under these opposite circumstances. It has been remarked, that over-warm clothing and a keen appetite in temperate weather are incompatible with each other; and doubtless this curious fact is connected directly with respiration. When the body is covered with a number of non-conducting materials, its loss of heat is greatly lessened, and the call upon respiration is therefore lessened in proportion: and this again tells back upon the appetite, and informs the system, so to speak, that less food is necessary for its wants. But reverse the condition;—let a man be clad in rags, and the intensity of his appetite increases proportionably. Hence it is a purely scientific fact that the poor and ill-clad creatures who tread our streets suffer most severely from the calls of hunger, although the sensation may be, perhaps, blunted in many instances by the frequency of its repetition. In the case of the poor man, respiration, supplied with but scanty fuel, and called upon to do more than ordinary duty to keep an ill-covered body warm, draws its supply from the structures of the body, and is no doubt the primary cause of that large amount of diseases of debility, whose victims are almost exclusively to be found among the poor.

It is ascertained that, in addition to respiration as a source of heat, there are several other causes in the living animal body by which the temperature of the whole system is maintained. In digestion, which is in great part a chemical process, a considerable amount of heat is extricated. Every mechanical

movement of the body, observes Mr. R. Hunt, occasions the development of heat; every exertion of the muscles produces sensible warmth; and indeed it can be shown by experiment that every contraction of muscular fibre is attended with the production of heat. There is no operation of the mind—not even the most idle thought—which does not produce a certain definite quantity of heat at the expense of brain-substance. Thus we see that the processes of digestion and respiration are not the only sources of animal heat, but that many others exist to which much of the natural temperature of the body must be referred.

Now although it is only a portion of the heat of the body which is *directly* due to animal oxidation, it must not be forgotten that the whole, or nearly the whole, of the heat is ultimately due to this source. We have before remarked that heat is but a kind of motion, that is, a kind of work. Now there are several kinds of work which are done in and by the body, and the force necessary for all of them arises from oxidation. First, there is what may be called the internal work, such as that performed in the ceaseless labours of the heart and lungs. Then there is the external work, done by the muscles in walking, lifting weights, &c. And lastly, to omit minor kinds, there is the *heat* work. Just as a steam-engine from the combustion of a certain weight of coal produces some heat and some mechanical work, so does the animal body by the combustion of food. The internal work of the body, having to overcome resistance, no doubt yields heat, but it is clear that this

heat is derived ultimately, though not immediately, from oxidation. "*Ex nihilo nihil fit*," is the language of modern science, and it is as true in the animal body as in any other department of nature. The food consumed by an animal may therefore be regarded as a just measure of the work of all kinds done in its body.

Thus reminded of the importance of the air to man and the animal world at large, we can feel the full import and accuracy of the expression, the "breath of life;" for only while we breathe, we live. There is more, therefore, than health in the soft airs which float around us. Upon them our very existence is every moment dependent. The breeze not only refreshes and cools the cheek, but gives strength, activity, and warmth to the entire frame. The learned Dr. Derham well said, "It is the air the whole animal world breathes and liveth by; not only the animals inhabiting the earth and air, but those of the waters too. Without it most animals live scarce half a minute, and others that are the most accustomed to the want of it, live without it not many days."

Yonder sleeping flock and those shade-seeking cattle are not less debtors to the air for life than is the cowherd on the river bank, or the shepherd under the elm. And, in the animals, the function of breathing differs but little from the same function as carried on in the human frame. Throughout the animal world there is found the same general principle to prevail with respect to this function; that is, the air is drawn into a cavity, upon the sides of which the vessels containing the blood ramify, and so the vital

oxygen of the air becomes applied to the blood, and is received into it, and so also the impurities and waste matters of the system, those at least which can be thrown off as gas or vapour, become discharged.

AIR-TUBES OF INSECTS.

There is a remarkable exception in the structure of insects. Here there is no organ like our lungs; but, strange to say, the air is conveyed by a series of beautiful fine pipes all through the body, even to the extremities of the imbs! This of course answers the same purpose as the other arrangement, the blood-vessels of the insect ramifying over these air-tubes, or *tracheæ*, as they are scientifically called. The same objects are effected by this arrangement as by the other, namely, the oxygenation of the blood, and the removal of its impurities. The breathing of those members of the zoological kingdom whose abode is in the waters will be noticed in the concluding part of this work.

Yet, while fulfilling these important duties, the air has others to discharge with respect to all animal bodies. We have already seen that the bodily frame throughout is in process of incessant change to a large degree, by the important function of respiration.

But few parts remain permanent. The tissues are nourished by the blood, their waste parts are carried off into the air, or rejected in other ways as excrementitious, and new particles take their place. In a little time these again, having served their turn, become effete, and are cast out of the body; yet these ceaseless changes do not affect the form of organs and their peculiar characters, unless, indeed, disease has been established in them. Curious truth! even the accidental impression of a long-forgotten injury, the honourable scar, or the effect of a severe laceration, remain in enduring memorial of the event upon the unchanging, yet ever altered, surface. Although undergoing perpetual alteration of their parts, the features, with all their characteristics, remain the same. Time may indeed brush the down off the young man's face, and blanch the ruddy hue of the maiden's cheek; it may pinch up the full features of youth into the withered lineaments of age; but a little mole on the skin defies the effects of time, and even of death—entering the tomb with the rest of the cold clay it had so long distinguished.

The atmosphere must be considered as one of the grand agents in the perpetual work of reparation and destruction. Its chemical energies are continually arrayed against the very existence of the human body. It is only by daily recruiting his strength that man is able, even for his brief allotted period of life, to offer a sufficient opposition to its effects to permit of his healthy existence. If his means of so doing fail, a destructive process immediately commences. The active lungs continue their incessant play, and the

swift-flowing blood still carries its oxygen to the tissues of the frame, and removes the products of their combustion. The stored-up fat quickly disappears; the round contour of health vanishes; starvation begins. The body slowly consumes away; the muscular tissues shrink and soften, and the haggard face and incipient delirium assure us that the work of death is going on at the nervous centres. If no help arrives, if the poor starving one is left to be "burnt with hunger," death sooner or later ensues, and the expression of Holy Scripture, which strikingly coincides with the philosophy of starvation, is realized; for the unhappy person is burnt alive. This effect is unquestionably principally due to the oxidizing influence of the atmosphere.

Our "earthly tabernacle" is but a tent after all; a tent which each moment undergoes repair and waste. The structure which is the scene of such incessant conflicts between the powers of destruction and reproduction, is already doomed. The balance cannot always be kept *in equilibrio;* equalization of the forces cannot always be secured. The surplus accumulates; the reparative powers give way before the onward march of the destructive. The body wastes down, as we say, with old age, and when not actually hurried into the grave by disease, dies at last of exhaustion. Well is it for him who is able to say with one of old, "I know that if the earthly house of this tabernacle be dissolved, I have a building of God, an house not made with hands, eternal in the heavens" (2 Cor. v. 1).

CHAPTER VII.

THE ATMOSPHERE AND VEGETATION.

LET us now proceed to make inquiry as to the mutual relations subsisting between the air and the luxuriant vegetation which surrounds us. How and in what way are these blades of grass affected by the summer breathings which pass in wave-like movements over them? The connection of animals with the atmosphere can, as a general rule, only be said properly to be established when they first draw the breath of life, although undoubtedly they are indirectly the recipients of its beneficial influences in their previous condition of immaturity. In birds, however, and oviparous creatures generally, from the earliest dawn of the principle of life within the shell this relation commences, only to cease with their death. The presence of the atmosphere is in like manner essential to the commencement of vegetable life. The seed can only begin to grow, or, in other words, to germinate, by virtue of its presence. Much, therefore, of the success of the florist, and, on a larger scale, of the agriculturist, depends upon this simple and forgotten condition of things. The seed must have access to air. It is also necessary that it should be surrounded by a medium, sufficiently, but not too moist, and that a moderate degree of warmth should

exist in the bed into which it is cast. It is a singular fact also, that while the luminous rays of light interfere with or even prevent this process, it appears necessary that the actinic or chemical rays of the solar light should reach the seed in order that it may germinate.

Placed in these favourable conditions, the seed absorbs moisture from the soil and oxygen from the air. A series of intricate chemical changes is immediately commenced, the gluten of the seed is altered, and its starch is converted into sugar for the nutriment of the young plant. Water and carbonic acid are also formed during this process, and in a short time the head of the young plant peeps above the soil.

Passing by the less important period of vegetable infancy, we are led on to that far more interesting time when the plant and the atmosphere enter into new relations with each other.

It has been already pointed out, that plants derive but a small proportion of their solid constituents from the soil in which they grow, and that the chief solid material of a plant is its carbon; also that many plants thrive with their roots buried in a vegetable mould extremely rich in carbon. Yet, on the question being put: Do plants derive their carbon from the mould? The answer has been in the negative.

Experiment has shown that it is impossible for a plant to receive nutriment by its roots in any other than a soluble, or gaseous form. The roots cannot take up solid matters. Applying this to our present subject, vegetable mould is found to be so little solu-

ble that 100,000 parts of water will only take up one part. The same might be said of many stones; in fact, some show a considerably greater solubility. A plant, therefore, whose roots meandered through a mass of powdered stones might be actually in a better condition, as regards its supply of soluble matter, than one growing in dry vegetable mould.

The atmosphere is the chief source of the carbon in plants. This may excite surprise and even challenge belief, but the fact may be proved. The wood of plants is derived from the carbonic acid which they breathe; thus air, or, more properly speaking, one of its constituents, is actually the food of vegetation! The orchis tribe, or, as they are commonly called, the "air-plants," furnish us with a beautiful illustration of this fact. These plants in their native haunts, are found upon the branches of lofty trees, seated as it were in state, and surrounded with groups of flowers and leaves, whose fantastic forms and gorgeous aspect make them objects of the most extraordinary character. The glowing colours and delicious fragrance of these plants have given them admission now to our conservatories. In the plant-stoves at Kew, orchids are to be seen growing upon pieces of dead wood, or out of a little moss in baskets, cocoa-nuts, and the like.

The sunshine, the heavy dew, the occasional shower, and the balmy air, are all their dietary. There are, it is true, a number of terrestrial orchids, and they, like other plants, derive a part of their carbon from the carbonic acid of the soil. In addition to the orchids, the extraordinary plant called the

"*stag's horn*" fern, is almost exclusively nourished upon the air. This plant is also to be seen at Kew, where in one of the tropical stoves it will be found growing upon a piece of wood. Its great leaves or

ORCHIDS GROWING ON A DEAD TRUNK.

fronds, in shape resembling antlers, hang down in a singular manner; and the whole plant presents us with a remarkable instance of a vegetable deriving little or nothing from the substance on which it grows, and yet flourishing in the greatest luxuriance upon a diet of water and air.

These plants are not strictly parasites, for they do

not live upon the natural juices of the branches on which they grow; therefore their carbon could not have been derived from the boughs on which they rest.

Some other facts may be mentioned on the authority of Dr. Schleiden. He observes: "The oil-palms (*Cocos nucifera* and *Elais guineensis*) grow in sea-sand. The culture of the latter is largely carried on on the west coast of Africa in moist, damp sand, not enriched by manure. Between the years 1821–1830, England alone imported from the coast of Guinea 107,118,000 lb. of palm-oil, and therewith about 76 million lb. of carbon (contained in chemical composition of this oil), drawn from a soil which in itself contained no carbon. . . . . According to Darwin, the richest maize harvests are obtained, from the interior of Chili and Peru, from the most sterile quicksands, which are never enriched by manure, and where only small streamlets from the Andes supply any water. . . . . The soil of the entire district of Brandenburg consists entirely of sea and blown sand. It is still in many places composed of a loose and pure quicksand of 100 ft. deep, and so moveable that it does not, as I have had opportunity of witnessing in the neighbourhood of Berlin, require any very high wind to change entirely the configuration of the surface. Young pines are found sometimes standing with their first branches buried in the soil; and after eight days with a naked stem, and the roots so exposed that one could creep through them! Yet this soil, as is seen in the Spriewald, so far as it is moistened by the rivers Spree and Havel, produces vigorous pine vegetation, which most certainly cannot draw all its

carbon from sources furnished by the soil, for it has never possessed it, nor has it been furnished to it by artificial processes."

It is remarked by Colonel Campbell that the cinnamon-tree flourishes best in a soil which consists chiefly of sand. He says: "The soil of the cinnamon garden, in the neighbourhood of Colombo (as well as that near Galle and elsewhere, in which the cinnamon-tree is grown; and in many places it is produced naturally), is a remarkable instance of the silicious kind. The surface of the ground in many places, where the cinnamon plant flourishes, is white as snow: this is pure quartz sand. Below the surface a few inches, where the roots penetrate, the sand is of a gray colour.

If these facts are considered, it will become apparent that the true source of the carbon of plants cannot be in the carbonaceous matter of the soil, seeing that vegetation is luxuriant even upon soils which contain little, or none of this element.

The carbonic acid furnished to the air by the various processes of combustion, respiration, and putrefaction, and from volcanic craters, is the true source of the carbon of the vegetable world. The composition of this gas is as follows:—

Carbon	27·27
Oxygen	72·73
	100·00.

Each hundred parts of carbonic acid contain by weight 27½ parts of carbon; if therefore we could remove the oxygen, carbon is left. Wood is com-

posed of carbon, together with the elements of water, oxygen and hydrogen; it contains other principles, but it is sufficient for our present purpose, to consider wood to be chiefly carbon. If therefore any structure is supposed to have the power of decomposing carbonic acid, of rejecting its oxygen, and of appropriating its carbon, modelling it for the peculiar purpose of its organization, the atmospheric origin of wood is rendered perfectly feasible. All we have to do is to show that plants possess this power.

The following experiment will doubtless be considered decisive as to the chemical influence of plants over carbonic acid. Dr. Priestley took a sprig of mint and put it into a glass vessel (see Fig.) which contained air mixed with a considerable quantity of carbonic acid. He then put it in a position where it was well exposed to the light, and left it for a little time. He subsequently analyzed the air contained in the jar, and to his astonishment found that all the carbonic acid had disappeared, and the air within the vessel contained more oxygen than common air! De Saussure performed similar experiments, and he found that not only had carbonic acid disappeared, but that actually a notable amount of oxygen had been added to the air, and the plants under examination had also increased in weight. Boussingault performed a yet more conclusive experiment. He enclosed a vine-

branch in a glass receiver exposed to sun-light, and containing air with a certain proportion of carbonic acid gas. The vine-branch was found to have absorbed and decomposed half the carbonic acid of this portion of air in a very short time. These plants in decomposing the carbonic acid, had appropriated its carbon and rejected the oxygen.

Let us now inquire what becomes of the other element entering into the composition of carbonic acid gas—namely, oxygen. Is it condensed and solidified, so as to form a part of the vital structures of the plant? Or is it again rejected, and again returned to the air? Upon the answer we are able to give to this question depends another important point,—Do plants purify, or do they vitiate the air? If they retain the oxygen of the carbonic acid they decompose, they rather tend to vitiate the air than otherwise, by removing one of its most essential ingredients. But if, on the contrary, they reject the oxygen, retaining only the carbon, they purify the air in a double sense; for they not only remove from it a dangerous ingredient, but add to it a salutary one in the element oxygen. In the day-time, and especially during sunshine, the numerous tiny pores with which the leaf is studded absorb carbonic acid and give off oxygen. To ascertain the point, the following experiment may be suggested to those who are sufficiently expert in mechanical and chemical manipulation to attempt it. Take any plant the branches of which are sufficiently long and well-clothed with leaves, (see cut) and insert it in a dish of mercury, bringing it up through the fluid into an

inverted glass jar, filled with air containing a slight excess of carbonic acid. The apparatus may be easily arranged, as in the cut, and the whole must be exposed to sun-light. If now, after a few days, the air in the jar is examined, by merely introducing a lighted taper into it, it will be found that the flame is much more brilliant than in ordinary air, which is due to the presence of an increased amount of

oxygen in the air of the jar. From this we learn,—and the experiments of Boussingault, Saussure, and Priestley, have with due accuracy proved the fact,—that plants in reality, while exposed to the sun, retain the carbon and give out the oxygen of carbonic acid, thus incontestably proving that one function is to purify the air of this gas, and to restore to it the element oxygen.

These grass-covered fields, and those leaf-crowned forests, are not the mere ornaments of the scene we contemplate: they do not flourish for nought, or live in vain. The pure air which lightly floats along the meadow, and softly whispers among the leaves of the wood, parts not with them as it finds them. It comes, bearing a deleterious ingredient; it departs, leaving it in some degree behind, and bearing away a healthful exchange of a fresh supply of oxygen. Thus, in beautiful connection, are plants nourished and strengthened; and in this very process the air is purified, and rendered more suitable for the existence of man and the animal world.

But this process only takes place under certain conditions. The popular belief about plants at night is less inaccurate: plants cease almost entirely to decompose carbonic acid at night, as they then absorb oxygen and give off carbonic acid. This is, however, only true of the green parts of the plant; for the flowers, even in day-time, absorb oxygen and give out carbonic acid. But the amount is trifling, and the benefit conferred by flowers is far in excess of the injury occasioned to the air.

We must refer to the influence of sun-light for the explanation of the cessation of this process at night. It has already been noticed that the rays of the sun exert a most important influence upon the vegetable kingdom. Perhaps there are few more pleasing subjects, in the Chemistry of creation, than that of the influence of light upon plants. The whole of the three principles resident in the sunbeam, namely, the luminous, actinic, and calorific rays, produce highly

interesting effects upon plants, and are, together, strictly necessary to the health, development, and perfection of the vegetable being. Let us briefly advert to the facts now known upon this subject. It has already been stated that, at the commencement of vegetable life, the actinic or chemical rays have been found to be indispensably necessary for the commencement of the process of germination. So soon as this process is ended, the plant having now raised its tender head into the light, it enters into a new connection with the air, and with the sunbeam. During germination the seed absorbed oxygen from the air, under the influence of the powers of vital Chemistry and actinism combined. But when the rays of unshaded sunlight fall upon the young leaf, its processes undergo change. It then becomes green, in consequence of the action of the rays of light upon some of the ingredients present in the leaves. And now, almost to the end of its existence, it pours out oxygen gas all the day long, in return for the carbonic acid it absorbs. It also begins rapidly to form wood; and we shall soon find that all the parts of the plant have acquired the hardness and firmness peculiar to woody tissues. The next important period in the history of the plant is its flowering season. The flowers, instead of decomposing carbonic acid, on the contrary, give out that gas, and absorb a considerable quantity of oxygen from the air. At the time of ripening, the fruit also absorbs oxygen from, and gives carbonic acid to, the air.

These effects, — the alternate decomposition of carbonic acid, and evolution of oxygen, with the

contrary process of absorption of oxygen, and evolution of carbonic acid,—appear to be dependent upon the alternate presence, or absence, of the solar beams. The plant is influenced, in succession, by the chemical rays, by the luminous, and by the calorific or heat-rays. The luminous, or pure light-rays, cause its leaves to decompose carbonic acid; and under their influence alone is the green colour, which is due to a substance named *chlorophyl*, produced. By the light-rays, therefore, wood is formed, and upon their stimulus depends the production of this refreshing green, which mantles over forest and field. But the heat-rays are not less essential to the plant. It appears that it is to the influence of the heat-rays that we owe all those flower-beauties in the vegetable world, which form such charming objects to the eye. It has been found that by separating the heat-rays from light, by means of a coloured glass, neither the light-rays, nor the chemical rays, will enable the plant to put forth flowers, or fruit. For this, the heat-rays are essential, and, in some wonderful and mysterious manner, by their assistance, the plant becomes crowned with its chiefest ornament.

We may thus recognise three stages in vegetable life, in each of which one of the three principles resident in the sunbeam comes most prominently into operation. 1. In the infancy of vegetable life, Actinism. 2. In the youth of the plant, Light, properly so called. And 3. In its perfection, or flowering-time, Heat. It must not, however, be imagined, that at no other period in the life of the vegetable being are these principles in active operation; this would be in

the last degree erroneous. In every process it is probable that the whole three forces are concerned,—in all the phenomena of growth, and in the various and complicated chemical processes taking place in the plant. But, at the three periods mentioned, it would seem that each becomes, in succession, of the greatest and most prominent importance to the plant. From researches which have been carried on with care for some years by Mr. R. Hunt, by means of an instrument called the actinograph, for measuring the intensity of the actinic power at different periods of the year, it appears that the actinic-rays are most active in spring, the light-rays in summer, and the heat-rays in autumn.

From these considerations we may learn, first, the importance of light to the vegetable world, and, secondly, the importance of light in order to the preservation of the purity of the atmosphere. It has been further suggested by Liebig, that those vast movements of air, known as the Trade Winds, are also instrumental in preserving the general balance of purity.

Again, the atmosphere is connected with the well-being of vegetation, by its influence on the soil. When land has been exhausted by successive crops, the remedy has been to let it lie "fallow," or, in other words, rest from bearing the same crops. The recovery of its lost ingredients is effected by the silent agency of the atmosphere. The command to the Jews of old, to let the land enjoy her sabbaths, had, no doubt, a direct reference to this object. The air and rain, with the alternations of heat and cold

exert a powerful influence upon the reposing surface. The mineral ingredients previously insoluble, become gradually dissolved under their operation, and a store of them is collected for the uses of the next year's vegetation. The land having "rested," the seed is again committed to the ground, springs up, and luxuriantly flourishes upon this gathered hoard. So on, alternately: the atmospheric influences continuing to reproduce, what man carries away, as fast as it is built up, in his corn and other plants, and appropriates to his own use.

The atmosphere, in all these ways, influences vegetation, and, indirectly also, animal life. Its influence extends to the preparation of the soil, is felt also in quickening the seed into life, in supplying it with food, and, finally, in reducing it when its course is ended,—when its functions are all fulfilled,—to the dust of the earth, and there preparing its ashes for the service of a future race.

PART III.—THE OCEAN.

"THE SEA IS HIS—AND HE MADE IT."

CHAPTER I.

ITS PHYSICAL CONSTITUTION, ETC.

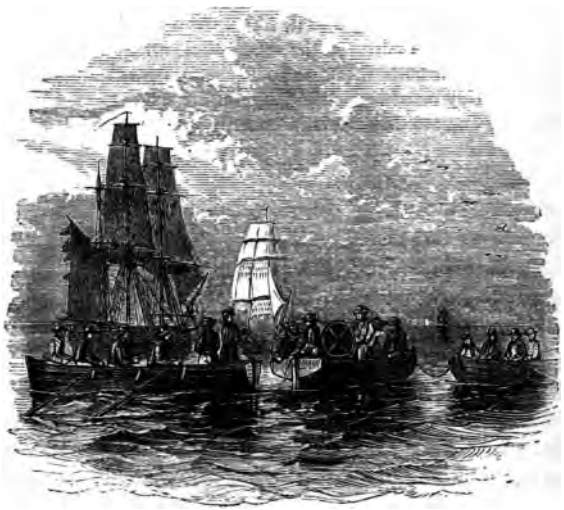
LET us transport ourselves to the sea-shore, to which the valley, where we have lingered so long, conducts us. As is well said by Locke, "the sea is a collec-

THE OCEAN.

tion of waters in the deep valleys of the earth." What matter of thought and investigation lies before us in the restless and majestic ocean, whose waves cast themselves at our feet, shedding their salt spray over us! Are the principles of Chemistry in action throughout this mighty deep, as we have seen them on the earth and in the air, producing their slow but ceaseless changes of form and matter? This inquiry it is our present object to satisfy. It may, however, be premised that the chemistries of the ocean are few and simple, far more so than those of earth, or air; but they are not less interesting, nor less important.

The greatest depth obtained by Sir J. C. Ross was in S. lat. 15° 3′. The weather being calm and the water quite smooth, soundings were tried for with 4,600 fathoms of line, or 27,600 feet. The method of taking this deep sounding is represented in the cut. The depth of the ocean is by no means uniform. Could we suppose the ocean emptied, and the bottom exposed, we should behold a great cavity very different from that of our imaginings. It would be seen that many of the varieties of hill and dale, of mountain, rock, valley and level plain, which characterize the aspect of nature on land, are repeated in the ocean. Doubtless a certain smoothness of aspect would in general be found to overspread these features, greater than we behold on land, in consequence of the levelling influence of currents, and of the deposit of sand and detritus. This is evident from the facts observed, in sounding, by means of the lead. Shoals, for example, which extend for miles,

and are surrounded on every side by such deep water that the lead cannot find a bottom, are manifestly mountains in the ocean, and would be seen as such were the water removed. Sometimes the shore of a country falls with a very gentle inclination; sometimes, and particularly near precipitous coasts, the bottom cannot be reached within a few hundred



DEEP SOUNDINGS.

yards of the rocks. The one would appear as a gently-descending plain, the other as an abrupt, precipitous, mountain, of great elevation. It must not, however, be supposed that no limit exists to its profundity, or that, except in the imagination of poets, it is without a bottom. In all probability its depth is

not greater than the height of the highest mountains on the land; the greatest hollows being supposed not to be deeper than from four to five miles, or thereabouts.

"Earth has not a plain
So boundless or so beautiful as thine;
The eagle's vision cannot take it in:
The lightning's wing, too weak to sweep its space,
Sinks half-way o'er it, like a wearied bird.
It is the mirror of the stars, where all
Their hosts within the concave firmament
Gay marching to the music of the spheres,
Can see themselves at once."—CAMPBELL.

The pressure of the atmosphere is greatest on the surface of the earth. In considering the physical properties of the air, Part II. Chapter I, we have seen that, at the sea-level, the air presses with a weight of nearly fifteen pounds. Not so with the ocean. We must not forget that on the surface of the earth we are at the bottom of the aërial sea; while, on the contrary, we are at the top, so to speak, of the sea of waters. Hence, as we descend into the ocean, the superincumbent pressure increases in proportion to the depth attained. How vast must this pressure become at the depth of four or five miles, when we reflect that the pressure even of such a light body as our air, equals on the earth 15 lb. on the square inch, water when perfectly pure being 770 times heavier than air! Experiments on this subject have often been made. It has been common to sink bottles full of fresh water, closely corked, into the ocean, when it has been found that the corks have

been driven in, while the fresh water has been replaced by salt, or the bottles have been crushed by the enormous pressure to which they were thus subjected. Pieces of light porous wood have been weighted and sunk and, when brought up again, have been found to be so condensed in their tissues, as to be incapable of floating any more, sinking like stones when thrown back into the water. In the experiments undertaken by various observers upon the temperature of the deep sea, by sinking thermometers, accidents repeatedly occur from the pressure of the waters above. Scoresby mentions that, during a whaling cruise in the Arctic regions, a whale, on being harpooned, dragged the boat under water, the crew escaping on to a piece of ice. When the fish returned for air to the surface, it was again struck, and then killed; it immediately began to sink. Fortunately, a grapnel was thrown over its tail, and its descent was thus arrested, though at imminent risk to the boat. On hauling up the line, it was found to have an extraordinary stress upon it, no fewer than twenty-five men being necessary to raise it. After several hours of toil, the boat which had been sunk was recovered, and was now so heavy as to require a boat at each end to keep it from sinking. On being examined, the paint came off in large strips, and the wood was so penetrated with water by the enormous pressure of the depths to which it had been dragged, that a piece of it sank like iron in the water, and it would not even burn when apparently dry and placed on a fire.

Although much less compressible than air, or

gaseous bodies, it is still capable of diminution, or increase in bulk, according as the pressure on its surface is greater or less. The experiment with the bottle of water sufficiently indicates this: but the fact has been accurately ascertained by philosophers. By means of an ingeniously constructed apparatus, Mr. Perkins obtained a striking evidence of the compressibility of water, in the index of the instrument, after its having been lowered deep into the sea, marking several inches lower than before it was sent down. At the depth of 20 fathoms, 20 cubic inches of sea-water only occupy the space of 19 at the surface.

In its profound depths, the ocean is darker than the darkest night. No twinkling of the stars gives variety to the dark expanse over head; and not even the brilliance of the noon-day sun can enliven these gloomy regions. Silent and black, it might be conceived to be the abode of eternal night. It has been a question how deep it is possible for daylight to penetrate into the waters. In the Tropics, where the utmost brilliancy of natural light is attained, the bottom of the ocean, at a depth of many fathoms, may be distinctly seen, and navigators state that the zoophytes and marine plants may be very clearly beheld, and that they appear most delusively near to the surface. Shells are visible in parts of the Arctic Ocean at a depth of 80 fathoms. In the seas around the West India Islands the bottom is distinctly perceptible at 30 fathoms. Ordinarily, about 700 feet appears to be the extent to which light penetrates into the ocean.

The colour of the ocean has engaged much atten-

tion, although not, in some instances, with that amount of entire success which could be desired. Sometimes it is of a beautiful blue; this is its natural colour; at others it is emerald green. Sometimes it appears streaked in brownish, or bright-green, or olive-green patches; sometimes it is even milky, and sometimes red, or of a reddish cast. Scoresby found, in the Arctic seas, that the green hue appeared to depend upon the presence of a vast number of semi-transparent spherical substances, with others resembling small portions of fine hair; and noticed further, that the whales delighted most to feed in these green patches of water. Darwin, while cruizing in the *Beagle* off the coast of Chili, found the vessel passing through a large area of water having a pale red colour. Obtaining a bucketful of this singularly tinged fluid, and placing a drop or two under the microscope, he found it full of animalcules, which darted about with great rapidity. A cubic inch contained more than a thousand of them, yet the surface tinged by their bodies extended for several miles. What an innumerable multitude must have been present in the whole!

The ordinary colours of the sea, however, depend undoubtedly in a great measure upon the influence of the water upon light.

Wherever water is clear and deep, it has the colour natural to it. The exquisite blue colour of the ice of most glaciers has been remarked by many. But the colour of the body upon which the water lies greatly influences the colour presented by the latter. In Arundel Park, Sussex, are several pools of fresh

water, in which pieces of white chalk lying at the bottom appear as if tinted with Prussian blue. At Capri, in the Gulf of Naples, are two grottos remarkable for the exquisite colour of the water seen in them. The sea at the Blue Grotto is most remarkably clear to a very great depth, so that very small objects may be distinctly seen, on the light bottom, at a depth of several hundred feet. All the light that enters the grotto, the entrance of which is only a few feet above the level of the sea, in the precipitous rock opening on the surface of the water, must penetrate the whole depth of the sea, probably several hundred feet, before it can be reflected into the grotto from the clear bottom. The light acquires by this means so deep a blue colouration, from the vast body of water through which it has passed, that the dark walls of the cavern are illuminated by a pure blue radiance, and the most differently coloured objects, below the surface of the water, are made to appear tinged with blue. In the Green Grotto the depth is less, and the yellow tint of the subjacent rocks alters the colour of the reflected light from blue, to green. Some parts of the Mediterranean Sea are found to present a reddish, or purplish hue; and in a bay on the west coast of Africa the waters always have almost the appearance of being tinged with blood: in both cases the effect is due to the colour of the bottom.

The beautiful phosphorescence, familiar to residents on the sea-coast, and well known to fishermen, who term the sea briny when its surface, on being agitated by the air or tide, flashes with phosphorescent light,

is generally supposed to be principally due to phosphorescent animalcules. Sometimes the appearance is so marked as to form a most curious and splendid spectacle. Waves of heaving fire rise and fall, flashing in the dark night with a lustre of indescribable brilliancy, and, as far as the eye can see, an ocean of fire appears to toss its waves, emitting a beautifully pure and pale light. Under the bows of the vessel, or in the water-line in her wake, ripples of flashing brilliancy play, and the path of the ship becomes marked with a long line of moving light. When water is taken from the surface it possesses the same luminous properties. Sometimes the luminosity has different tints; in tropical waters it is often white as snow, and the whole surface of the deep looks like a field covered with newly-fallen snow. In the Gulf of Guinea the surface of the water sometimes appears of the most brilliant white. The cause, in this instance, has been supposed to be vast numbers of small crustaceous animals, which have the singular property of emitting a white light.

Sometimes it is of a ghastly blue, and the appearance then presented is more than ordinarily terrifying to the superstitious. Again, sometimes it is of a fiery red, or even scarlet, as though some marine monster's blood did

> "The multitudinous seas incarnadine,
> Making the green one red."

Sometimes also the tint is green; at other times, yellow.

In many cases this power of emitting light appears

to be a vital property connected with the existence of marine beings. Dr. Macculloch, who laboriously investigated this curious and interesting subject, writes :—" I believe the power of producing light to be an universal property in the marine tribes. I have never found a species in which it did not exist." The luminosity of some fishes depends upon the minute phosphorescent creatures, *Nereis noctiluca*, attaching themselves to the scales of fish, and thus illuminating the surface of the animal on which they rest. Many of these phosphorescent creatures are of extreme minuteness. The little being represented in the cut, *Noctiluca miliaris*, does not exceed the one-thousandth

NOCTILUCA MILIARIS (magnified).

of an inch in diameter. Millions may be easily contained in a bucketful of sea-water. On examination under the microscope, the light no longer appears as an uniform glow, but is resolved into a multitude of flashing sparks.

In the British seas, these little animalcules are often found congregated together in unnumbered millions.

There is no doubt that this phosphorescence is a chemical phenomenon, and is connected with the slow oxydation of some compound containing phosphorus, but the question is too difficult a one to discuss in this work.

As we sink into the ocean the temperature decreases. Just as the progressive decrease of temperature in the air, as we ascend, is marked by zones of vegetation which become more and more northern, so as we descend into the sea, there are zones of temperature, marked by the character of the marine animals which exist in them. In the lower regions, these animals consist of species as strikingly resembling the northern ones, as the higher vegetation in a lofty range of mountains resembles that of the northern regions. Even in the fourth region nearly fifty per cent. of species are identical with northern forms. Professor Forbes found a difference of temperature between the highest and lowest zone; the latter at the depth of 300 fathoms amounted in summer to from 26° to 30°; the temperature of this zone was 55°, while that of the upper zone ranged from 76° to 84°, during eight months in the year. It is highly interesting to find that the inhabitants of the deep are thus carefully accommodated and distributed, far out of sight of man, as is the case with the vegetable and zoological dwellers on the surface of the earth.

The warmest part of the ocean is, in temperate and tropical regions, at its surface, and it is, in its usual and mean condition, somewhat warmer than the bed

of air immediately resting upon it. This is the result of a very simple law connected with what is termed convection (or carrying) of heat in fluids. The warmer particles of water, expanded by heat, become lighter than the surrounding particles of colder water, and consequently rise to the surface; while the cold particles sink, until they meet with a stratum of water of similar temperature and density to their own.

In the conduction of heat each particle takes up the motion of its neighbour and passes it on. In the case of fluids, heat is actually carried by the motion of the particles from one position to another, and is thus slowly diffused throughout a liquid; the coldest particles being at the bottom, and the warmest at, or near, the surface.

The temperature of the ocean is greatly influenced by its depth. Under ordinary circumstances, it appears, that water close by the shore is colder than that far from the land. Sailors might thus frequently be made aware of the existence of shoals, or sand-banks, without the aid of the lead, were it not that a number of circumstances of local origin interfere with the temperature of the water near land, and thus render what might otherwise prove a valuable sign, far too uncertain to be relied upon. It is supposed that the influence of the seasons is not felt by the ocean below the depth of 300 feet.

We must now advert to a remarkable fact in the physical history of the ocean, and of water generally. The particles of cold water, being the heaviest, descend, while the lighter warm particles remain on

the surface. If we suppose this process to continue, the ultimate result would inevitably be that our lakes, and the shallower parts of our seas, would soon be covered with a dense solid layer of ice, which would increase until they became almost choked up with it. Such an altered condition of the waters would rapidly affect the climate; our summers would become cold and cheerless, our winters long and severe. But this result is prevented by a law observed in water as it is gradually reduced in temperature. In cooling, it is true, it becomes gradually denser and heavier; but when it has reached the point of 39·2° F., further cooling reverses the state of things and the particles actually become specifically lighter. The descent of water cooled below 40° is thus effectually arrested. When ice is formed, it is so light as to float on the surface of the water, and in so doing covers and protects water actually warmer than itself below. Besides this, in the act of freezing, each pound of water gives up 142 degrees of heat, by which the surrounding water is raised in temperature.

At the point at which the contraction ceases we have the maximum density of water; from this point downwards, to its freezing point, it expands.

The freezing of sea-water is also lowered by the presence of salt, so that 28·4° is its freezing point, instead of 32° F.

In consequence of the bad radiating properties of water, the temperature of the ocean is much less subject to variations than that of the air, and the variations that occur are small in amount. The result of this is, that the air overlying the ocean is

much more uniform in regard to temperature, than that over the land. In parallels where the range of the thermometer suspended in air over land amounts to 20° or 30°, or even more, a thermometer suspended over the ocean's surface does not range more than 5° or 6°. Thus the effect of the presence of the sea upon a climate is to equalize it; and this is remarkably the case in the climatology of very small islands. In the Channel Islands, for example, in Guernsey and Jersey, this influence is most observable: frosts are of rare occurrence there, and of the shortest duration, and the extreme of heat is seldom experienced. Summer and winter are not separated by the chasm which divides them in the climate of great continents, and the excessive degrees of temperature are almost unknown on either side of the thermometric scale. The influence of such a climate upon the floriculture and horticulture of these islands can scarcely be believed. The most delicate and beautiful plants which in England must be carefully kept, during the winter, in our conservatories, and cherished with artificial warmth, are there exposed without injury all through that part of the year; and the markets in summer exhibit proofs of exuberant fertility of soil scarcely to be expected even in districts much farther south than is their position. The equalizing influence of the ocean is felt universally, through every region of our globe, to a greater or less extent. The waters heated in warmer regions are directed by the various currents of the ocean to others, where the solar influence is much more feeble, and roll down the shores of coun-

tries lying in latitudes far remote. There can be little question that, were the present relation altered that alteration would speedily be attended with a modification of climate, and, as a result, with important alterations in the number and varieties of the animals and plants occupying the surface of the present earth.

The temperature of the sea diminishes as we descend: the bottom water of the North Atlantic has a temperature a little above 35°.

The ocean is the great reservoir from whence, raised by the process of evaporation, the earth derives its supply of water, and to which all springs and rivers carry back their contents. A system of circulation is thus established on the grandest scale: water rises as vapour, assumes the form of clouds, descends on land in the various conditions of rain, hail, snow, and dew, and becoming then collected in larger currents, seeks the ocean again to undergo a similar series of changes. A small portion of the saline contents of the sea is thus made available to the necessities of plants on land, by uniting with the ascending vapour, and being precipitated in the descending shower.

CHAPTER II.

CHEMISTRY OF THE OCEAN.

IN the same manner as the air is the reservoir of everything that is volatile, the waters are the receptacles of everything that is soluble.

The waters of the ocean have been repeatedly analyzed, and the result has been to show that common salt, or chloride of sodium, constitutes by far the largest proportion of the whole of the saline matter present. As to its density, if pure water is represented as 1,000, sea-water is about 1,027. The subjoined table gives an analysis of the sea-water taken off the coast of Havre :—

1000 grains contained—	
Water	968·414
Chloride of sodium	24·632
Chloride of potassium . . .	·307
Chloride of calcium	·439
Chloride of magnesium . .	2·564
Bromide of magnesium . .	·147
Sulphate of lime	1·097
Sulphate of magnesia . . .	2·146
Carbonate of lime	·176
Carbonate of magnesia . . .	·078
Carbonates and iodides, ammoniacal salts, organic matter, &c.	Traces
	1000·000

In an analysis by MM. Malaguti, Durocher, and Sarzeaud, the presence of copper, lead, and silver was detected in sea-water, and to a larger extent silver was found in the ashes of sea-weeds. Recent researches have confirmed these results, and indeed have still further increased the list of substances found in the ocean. From this it will be evident that sea-water is a fluid containing a large number of chemical constituents. While, however, the analysis of sea-water, carefully conducted, will generally exhibit the presence of these ingredients, their proportion is subject to variation under different circumstances: the Mediterranean sea-water is considerably more highly charged with saline matter than the waters of the ocean outside the Straits; an effect which appears to be due to the immense evaporation taking place from its surface, which carries off an enormous volume of water in the form of vapour, to supply the place of which a strong current sets in from the main ocean, through the Straits of Gibraltar. In other inland seas, on the contrary, and generally, the amount of saline matter is diminished. The explanation of this appears to be, that such seas receive a very large addition of fresh water from the coast around them, and from one or more great rivers which may flow into them. The Baltic Sea is thus remarkably contrasted with the Mediterranean; for while the latter has a density of about 1·029, the waters of the former have a density very little above 1·015. Near the mouths of great rivers, as is naturally to be expected, the quantity of the saline contents of sea-water is much lessened; thus, the diluting

influence of the great American river, Amazon, is distinctly perceptible for a distance of upwards of 300 miles from its mouth.

The amount of salts in different parts of the sea ranges from 3·25 to 4 per cent. But when we come to reckon the total quantity of these saline substances dissolved in the sea, we cannot but be astonished at their vast amount. For every square mile of land we have three square miles of water; and on a rough calculation it is found that the whole range of the Himalayas does not exceed in bulk one-third of the saline substances contained in the ocean!

The chief cause of the variations in the total quantities of saline matter present in the waters of different seas, are—1st, the influence of evaporation, which concentrates the fluid by removing a portion of its watery particles; and 2nd, the influx of fresh water from the land, or from the atmosphere. In consequence of its saline contents sea-water is more dense and heavy than fresh water. This is occasionally turned to some advantage by navigators. In the narrative of the voyages of the *Adventure* and *Beagle*, Captain Fitzroy remarks, in their expedition up the river Santa Cruz, in Patagonia, at a particular point: —"The water was fresh over the surface, and sometimes it is quite fresh even into the estuary; but in filling casks, or dipping anything into the stream for fresh water, it is advisable not to dip deep, or to let the hose, if one is used, go many inches below the surface, since it often happens that the upper water is quite fresh, while that underneath is salt. This occurs more or less in all rivers which empty them-

selves into the sea: the fresh water, specifically lighter, is always uppermost." The saline matter of the lower stratum mixes with the fresh water by a force analogous to that with which gases mix with each other—the force of diffusion.

One remarkable feature of investigations into the Chemistry of the sea is too important to be passed by, namely, the uniformity of chemical composition of sea-water, notwithstanding the circumstance of its varying saline quantities. This apparent paradox may be explained in the following manner: if a solution containing certain quantities of salts, six in number, the relative proportion of each of which is known, be dropped into, 1st, a pint of water; 2nd, a quart; and 3rd, a gallon,—and equal parts of these waters are analyzed, we shall have the following results:—In the first we should find a considerable quantity of saline matter, in the next less, and in the third still less; but the proportion of the salts in this saline matter would not vary in the least, just for the same reason that a drop of this saline solution has exactly the same chemical composition as the whole quantity. So in the great ocean: in parts it has more, in parts less, saline contents; but their number and proportion are pretty generally the same in all parts. If the saline matter were of a blue colour, we should find the sea deep blue at the tropics, paler toward the poles, and along all our coasts a pale blue hue would extend, curving farther into the sea near the mouth of every large river than elsewhere.

From a review of the main constituents of our globe, it would appear natural to expect that the water

which surrounds so large a portion of it, and is the great reservoir for its watershed, would contain sodium, potassium, calcium, and magnesium in combination.

There are not many other subjects upon which more erroneous opinions have been held than upon the origin of the saline matter in the ocean. For a considerable time it was said, that the saline matter was derived from the solution, by the waters of the sea, of certain conjectural masses of rock-salt, which were supposed to exist at its bottom; and that the ocean became salt, as a dish of tea becomes sweet, by simply dissolving the soluble matters conveniently arranged at its bottom.

The presence of the saline matter is now accounted for, upon the view already offered; namely, that the saline matter owes its origin to the ocean being the receptacle for the drainage and washing out of the soluble parts of the earth, carried down to it in the rivers. Accordingly we are not surprised to find in it traces of all those substances thus derived, which are capable of existing together in the same solution. Thus, phosphate of lime, silica, oxides of iron and manganese, fluoride of calcium, and salts of silver, copper, and lead have been detected in the sea. A portion of the copper sheathing of ships, which is gradually dissolved and removed by the action of the chlorides, &c., of the sea, is found to be replaced by silver. In this way it is calculated that one ton and a half of silver is yearly obtained from the sea.

The saline condition of sea-water is but an exaggeration of that of ordinary lakes and rivers, the materials

are the same, and of necessity so; the ocean being, in fact, the great depository of all the soluble substances which, during many ages, have been separated by a process of washing from the land. The case of the sea is but a magnified representation of what occurs in every lake into which rivers flow, but from which there is no outlet except by evaporation. Such a lake is invariably a salt lake, nor can it be otherwise; and this condition disappears when an artificial outlet is provided for the water. It should be remembered that the saltness of the ocean is very far exceeded by that of several inland lakes of the kind described: that of Aral, the Caspian Sea, and the Dead Sea in Judæa, are remarkable examples.

The unequal rate in which different salts diffuse upwards into the fresh water above, explains in some measure the discordant results obtained by different chemists in examining the waters of the Dead Sea. It appears that the amount of saline constituents in this inland sea varies in different parts from 11,000 to 21,000 grains in the gallon. How different is the proportion of solid matter in some rivers may be judged from the following analyses (p. 268) given in Roscoe and Schorlemmer's treatise on Chemistry.

The waters of the Dee and the Don, in Aberdeenshire, drain a granite district, and are soft waters. The Thames water is temporarily hard, and the Trent water permanently hard.

Just as the power of diffusion tends to preserve the uniform composition of the air, so a similar force tends to intermix the saline constituents of the ocean with the enormous volumes of fresh water continually

	Grains per Gallon.			
	Thames.	Trent.	Dee.	Don.
Calcium carbonate ...	10·80	0·32	0·85	2·23
Calcium sulphate ...	3·00	21·55	0·12	0·13
Calcium nitrate	0·17	—	—	—
Magnesium carbonate ...	1·25	5·66	0·36	1·07
Sodium chloride	1·80	17·63	0·72	1·26
Silica	0·56	0·72	0·14	0·52
Ferric chloride and alumina	0·27	0·50	0·06	0·27
Calcium phosphate ...	Trace	Trace	Trace	Trace
Organic matter	2·36	3·68	1·54	3·06
	20·21	50·06	3·89	8·54
Hardness	14·00	26·50	1·50	3·00

added to it. Without this, the ocean would in time become divided into an underlying, constantly increasing stratum of salt water, and an overlying stratum of fresh water.

The presence of the salts is useful in checking evaporation too, in causing sea-water to freeze at a lower temperature than fresh-water, and in communicating greater buoyancy. It likewise renders its putrefaction less easy than if it were fresh. As we shall have again to remark, there exists a strict connection between the functions of the tenants of the deep and this saline matter. If, therefore, we are to regard the presence of certain principles in the air satisfactorily accounted for by the recognition of their usefulness to animals and plants, the same reasoning may be applied to the ocean; and we may with justice regard its saline contents as specially adapted to the functions and purposes of its varied inhabit-

ants; while with equal truth we may affirm, that the animal and vegetable existences, which it supports, are specially adapted to live in it.

In addition to the saline matter, distinct evidence of the presence of organic matter is always obtained in the analyses of sea-water. The organic matter may be due to minute animalcules, or it may consist simply of some products of animal decomposition. Sometimes it exists in very large proportions in sea-water; M. de Tessen observed in the sea, near the Cape of Good Hope, a very singular instance of this kind. Innumerable minute spherical bodies filled the water, and thickened it to such a degree as to give rise to a faint crackling sound on its being agitated with the hand. Some of this water, when strained through a cloth, left half its bulk of this organic matter, consisting chiefly of the bodies of animalcules. It was highly phosphorescent.

Among the several causes of the phosphorescence of the sea, the most efficient is the existence of organic matter in a state of dissolution.

The following singular account of a large luminous spot in the sea, observed by Captain F. Eardley Wilmot, deserves attention. On his voyage home from the Cape of Good Hope, in the spring of 1850, he observed one night a remarkable, though not very uncommon, appearance of the sea:—"The sea was covered with so brilliant a surface of silver light that we could see to read, and the shadows of the ropes were strongly marked. We sailed through it for about four hours! In one place it had an edge, and we sailed out of it for nearly half an hour, when we

again entered it as abruptly, and finally left it, where the edge of the illuminated part was strongly defined. The water was taken up in a clean bucket, and put into a carefully-cleaned bottle, about 10° north latitude." This bottle, with its contents, was submitted to Faraday for analysis, the result of which is given in the following note:—"I have examined the water, and it is peculiar in some points. It contained much sulphuretted hydrogen, and also a portion of solid deposit, which was about one-half sulphur and the other half organic matter. There has, no doubt, been considerable change in the contents of the water, and I cannot now recognize organic forms; but the presence of the animal matter, the sulphur, and the sulphuretted hydrogen, all agree with the idea that the water, when taken up, was rich in animals or animalcules." Nevertheless, in the absence of any evidence to prove the existence of luminous animals in this water, it is possible that it contained organic matter in the first stages of putrefaction.

Mr. Darwin states that after using his towing-net during one night, he allowed it to become partially dry, and having occasion twelve hours afterwards to employ it again, he found the whole surface sparkle as brightly as when first taken out of the water. It does not appear probable in this case that the particles could have remained so long alive. On one occasion, having kept a jelly-fish, of the genus *Dianæa*, till it was dead, the water in which it was placed became luminous. Professor Ehrenberg, during a stay of five months at Tor, on the Red Sea, was frequently engaged in examining the sea-water, which was found to be very

full of small slimy particles without any determinate form, often having the edges jagged, and which emitted light on stirring the water in which they were found. They covered the marine plants, corals, &c., which consequently appeared luminous; every stroke of the oar caused them to sparkle; but he was never able to detect organization in any of these particles, and he could never satisfy himself that any of the microscopic animals which he found with them in the water gave out light. They did not unite and form large slimy masses, but were dispersed about in small flakes. On examining the water after a violent storm at Heligoland, Ehrenberg found no infusorial animalcules in it; but quantities of morsels of gelatinous matter, often torn and ragged, which emitted light, and small gelatinous globules, with jagged edges occurred, similar to those which he obtained in the Red Sea. During his stay at Heligoland, he often observed as it were chains of luminous matter floating in the sea, which on examination proved to be masses of luminous *Medusæ*, detached and torn by the violence of the sea. Darwin says, "The same torn and irregular particles of gelatinous matter described by Ehrenberg, seem in the southern as well as in the northern hemisphere to be the common cause of this phenomenon. The particles were so minute as easily to pass through fine gauze, yet many were distinctly visible by the naked eye. The water when placed in a tumbler and agitated, gave out sparks, but a small portion in a watch-glass scarcely ever was luminous. Observing," he adds, "that the water charged with gelatinous particles is in an impure state, and that the

luminous appearance in all common cases is produced by the agitation of the fluid in contact with the atmosphere, I am inclined to consider that the phosphorescence is the result of the decomposition of the organic particles, by which process (one is tempted almost to call it a kind of respiration) the ocean becomes purified."

Recent discoveries render it highly probable that this view, which is also held by Professor Ehrenberg, is the correct one, and that while it is certain that many marine creatures possess the faculty of emitting light, yet that this phenomenon, when occurring over a large surface, is due to a sort of natural purification of the water, by exposing these organic matters. Professor Schönbein says: "It is well known that the phosphorescence of the sea is intimately connected with the motion of its waters, or, to speak more properly, that the phenomenon is dependent upon the particles of these waters being brought into immediate contact with the atmosphere. When a ship moves about, or the wind happens to agitate the sea, the surface of the brine is continually renewed, and consequently new particles of organic matter are every moment brought into contact with the surrounding air." Hence we are to consider the light given out by the waters of the ocean as the effect of a process of oxidation taking place on a most extensive scale, which process is carried on either by the free oxygen of the atmosphere, or by that of the ozone produced by a peculiar property of the organic particles in the sea-water. The source of the organic matter in the waters of the ocean

lies in the decomposition of innumerable marine animals daily dying in its depths, and also in the organic matters brought down and swept into the ocean by rivers.

It has been found, that in fresh water also there is generally a considerable amount of organic matter: it is greatest in summer. Its quantity is diminished by rain, but chiefly by oxidation, when the water has to run a long way in open channels. An examination into the organic constituents of sea-water furnishes a similar series of facts.

In addition to the ingredients hitherto recognised as producing a portion of the saline contents of sea-water, another has been discovered by Dr. Wilson. By some ingenious experiments upon the crust of the steam-boilers of steamers he obtained conclusive evidence of the presence of fluorides, in the production of hydrofluoric acid vapour, which has the property of instantly corroding glass. By properly treating the crust thus obtained he was able to etch several pictures on glass, which were exhibited at the scientific meeting before which his experiments were brought. Fluoride of calcium has been found both in the waters of the German and other oceans, of the Firth of Forth, in the teeth of the walrus, and in the ashes of marine plants, and it has been detected in several mineral springs. Professor Forchhammer states that he has examined many shells and marine products from various localities, and they all gave evidence of the presence of the same body, the quantity being always greater in sea than in land animals.

The shields of many infusorial animalcules found in sea-water are largely composed of silica; and silica has been found to be one of the mineral ingredients of sea-water. These animalcules may, however, be able to obtain it even when it exists merely in a state of mixture in water.

As with the air, so with the ocean; occasional ingredients are met with. Darwin says he saw a considerable tract of the ocean on the Mexican coast covered with a thin, iridescent coat of oil. The sea near the Cape de Verd islands is not unfrequently seen covered with a film of petroleum. In the waters which bathe the coasts of volcanic regions, evidence exists to show that occasional ingredients fatal to animal life are added from time to time to the sea. Thus we are informed that at the eastern extremity of Java there is a lake containing sulphuric acid, a quarter of a mile long, from which a river of acid water issues which supports no living creature, nor can fish live in the sea near its confluence. It is one of the frequent phenomena of earthquakes, that the sea-water of the regions where they occur is covered with shoals of fish poisoned by the addition of some deleterious ingredients to the water. After a volcanic eruption in Iceland the fish all deserted the sea-coast, thus showing that something had been added to the water unfavourable to their existence.

There can be no question that a self-purifying property attaches to sea, as to other water. A portion of it serves as nutriment to the various living creatures peopling the waters; yet another is decomposed by the influence of dissolved oxygen. In

consequence of the continued deposit which is taking place over a great part of the ocean bed, the products of these decompositions, when insoluble, are buried at the bottom, and soon so entirely covered over with a layer of detritus, as effectually to protect the overlying waters from their influence. This purifying process is largely assisted by the mechanical action of the waves. The occasional ingredients, locally present in the waters of certain coasts, are commonly removed by the ordinary effect of chemical decomposition. The carbonate of lime, for instance, which is brought down so abundantly by the rivers, and which is usually their chief saline ingredient, is removed from the sea by mechanical, chemical, and vital action. A portion held in suspension is precipitated, and accumulates as mud at the bottom of the sea; another portion is deposited, owing to the escape of the carbonic acid which held it in solution; while the greatest part is taken from the water by the agency of vegetable life. These marine plants constitute the food of many marine animals, which form their shells, testæ, bones, &c., chiefly of the carbonate of lime they thus acquire.

CHAPTER III.

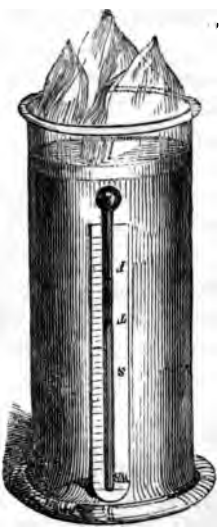
MOVEMENTS OF THE WATERS.

"Time writes no wrinkle on thine azure brow,—
Such as creation's dawn beheld, thou rollest now,
Thou glorious mirror, where th' Almighty's form
Glasses itself in tempests, in all time,
Calm or convulsed, in breeze, or gale, or storm,
Icing the pole, or in the torrid clime
Dark-heaving: boundless, endless and sublime,
Th' image of eternity, the throne
Of the Invisible."

THE restlessness of the ocean is a fact so familiar to us as to have passed almost into a proverb. The "troubled sea" is an expression, the frequency of the use of which sufficiently indicates that the movements of the waters are phenomena of the most familiar observation. As the tide continues flowing in and threatens soon to cover the spot where we stand, it is impossible not to feel strongly impressed with the fact, that ceaseless motion appears to be a very law of the constitution of the magnificent element we behold. Yet, in reality, just as its particles are more dense and less elastic than those of the air, the movements taking place in the waters, are not nearly so extensive or so various, as those which incessantly agitate the air round and above us, even when it appears in the most quiescent condition. The fact that every ripple which agitates the surface

of the water is visible to us, while the most violent commotions of the air are wholly invisible, accounts for the disposition we feel to give to the waters, rather than to the air, the character of restlessness.

Thus, heat affects mainly the uppermost layer of the sea. Heat applied to the surface of the ocean can produce little or no movement in its particles: being expanded by heat, and thus rendered lighter, they of course cannot sink, but remain stationary, or nearly so, at the surface. A very simple experiment will prove this: if water be poured into a tall vessel, nearly to its brim and a sensitive thermometer be inserted in it, as shown in the cut, so that the bulb shall be just below the surface, and then a quantity of pure spirits of wine be poured upon the water, and lighted, it will burn for some time, and of course communicate heat to the surface of the water; yet the thermometer, separated only by a thin layer of water from the burning spirit, will not indicate any, or only the smallest possible rise of temperature. This is because fluids are bad conductors of heat. If the flame were applied to the bottom of the water (as shown by the woodcut, p. 278), instead of its surface, the result would now be different, and the liquid would



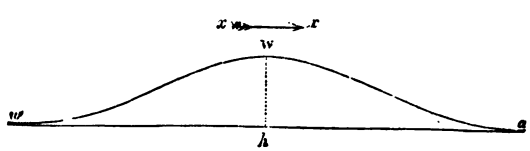
boil in consequence of what has been before called the convection, or carrying upwards of heat, by the light and expanded particles, as they rise to the surface of the fluid. Let us perform the converse of this experiment, and place, instead of a flaming layer of spirit, a flat piece of ice upon the surface of the water. The effect is immediately perceptible by the falling of the thermometer; the particles of water being cooled become heavier, and sink rapidly downwards. Hence it is evident, that while heat, applied to the surface, produces little or no movement in the particles of water, the application of cold, on the contrary, is a constant cause of motion. In the air, heat causes the particles to ascend; for it is applied chiefly to the lowest stratum resting on the heated earth; in the water, cold being applied to its surface causes the particles to descend. Direct observations are still required on this subject, but it appears probable that this class of movements takes place most actively in regions of moderate temperature. Near the equator, during the day, the upper stratum of water becomes greatly heated by the sun's rays, but very little disturbance of its particles is thus produced. Again, in

the colder regions about the poles, the surface of the water is covered with a dense and solid stratum of ice, or the water when not frozen is scarcely ever higher than 40°, at which point its particles lose their tendency to sink; and here movement is of course arrested. In temperate regions, therefore, while the nights are very cold, although not so cold as to reduce the temperature to 40°, this movement goes on most actively. The surface particles constantly losing heat, and so becoming specifically heavier than the particles beneath, sink: while their place is supplied with warmer particles from below. By placing several lumps of ice in a tumbler partly filled with water, these movements can be very distinctly perceived: the cold particles, in descending, become visible in consequence of the effect of their greater density upon the refraction of light, but their further movement downwards is arrested in obedience to a law already explained at p. 259.

The movements with which we have thus been occupying ourselves are generally removed from sight; those which are next to come under our notice, and which are among the most sublime phenomena of the ocean, appeal both to the ear and to the eye, as we behold them agitating mass after mass of water, until they dash at length, with a hollow sound, in foaming breakers at our feet. Far as the eye can reach across the surface even of this comparatively tranquil ocean it beholds nothing but line after line of heaving waves; now and then a taller and broader billow than the rest, marking its pre-eminence by a white crest, curling on its summit.

It might be supposed that little interest attached to the phenomena of waves beyond their beauty, their sublimity, or their force. Yet there is much philosophy, and that of a very abstruse order, concerned in the explanation of their movements! Incredible as it may appear, there is a real harmony and order observable in this seemingly disordered and confused mass of waters. Some of these waves are round and long, others are high and sharp; some advance with a great, others with a less velocity; and all present a certain general form familiar to the mind as the form of a sea in agitation, which at once distinguishes it from all other phenomena. How striking the thought that not one of these apparently free and fetterless billows, which have supplied poets with the most beautiful similes of liberty and unrestrained action, can move but in obedience to certain laws which control and direct them! To us, nothing in nature appears so unshackled; in reality, not a wave heaves, but is under the influence of laws which prescribe its movement, velocity, and form.

The following parts are recognised in a wave:—Its



highest part is called the *crest*, w in the diagram. From w to *a*, is called the *front;* from w to *w* the *back;* from w to *h* the *height;* and from *w* to *a* the

amplitude; a is called the origin, and *w* the end of the wave. The arrow *x x* shows the direction of the movement of the wave.

Wave-like movements in the waters of the ocean arise from two causes, the attraction of the sun and moon, and the power of the wind. What are called *tides* are, in reality, vast wave-like movements due to the attraction of these heavenly bodies, but in their effects influencing vast portions of the watery regions of our planet. Mr. Scott Russell, who has for many years paid much attention to this subject, calls this the Great Primary Wave. In merely beholding the phenomena of the ebb and flow of the tide, it may be difficult to realize the fact that these effects are due to the rise and fall of one mighty wave, which rises in mid-ocean, and, in falling, casts its wide-extending waters on the shores of half the world. Under the influence of the lunar, or at stated periods, of solar and lunar attraction, a vast mass of the waters of the ocean is raised above its general level; obedient to the laws of hydrostatics and of gravity, this great mass of water sinks down again, spreading in every direction around, until at length it rolls its waves upon every shore, which, on attaining the highest point to which they ordinarily extend, produce the phenomenon of high tide. When again the waters are "gathered into a heap," they become withdrawn from the shore: it is then low water.

The velocity of this great tidal wave varies from 10 to 100 miles an hour, and between 50 or 60 hours are occupied in its reaching our shores from the time of its dispersion. This wave, however, is

not the less real that its length is so great; for while one end touches Aberdeen, the other reaches to the mouth of the Thames and the coast of Holland. Though its extent and magnitude render it impossible to be recognised as a wave by any single observer, we are able, by stationing numerous observers along different parts of the coasts, to compare its dimensions, and to trace its progress at different points, and so to represent its phenomena to the eye and mind, on a small scale, as to comprehend its form and nature as clearly as we do those of a mountain range.

Whenever the great tidal wave is met by an opposing current from the waters of some large river, it raises a mass of water of great height and force, called the "bore." We know little of the power of this remarkable phenomenon on our coasts, although it is observable in some of the rivers, such as the Severn and Trent: but in India, the bore of the Ganges has long had a fearful reputation. Sometimes it appears as a roaring mass of many waters, four or five feet high, often overwhelming with destruction all the smaller craft exposed to its power: in other rivers it attains a still greater magnitude. But the grandest display of this phenomenon is described as occurring near the mouth of the river Amazon. At the ebbing of the tide this mighty stream pours down at spring-tides a vast volume of water, with great velocity, into the ocean. The current, at a little distance from land, meets with a powerful opposing oceanic current, and the result of this conflict is sometimes to raise quite a mountain of water, which carries terror and desolation along its entire track. Such is

the violence of this extraordinary phenomenon, which is called by the Indians the *Pororoca*, that the very islands tremble during its passage.

The second order of waves is produced by the action of the wind. Poets speak of the "inconstant billow;" and vainly, as might be supposed, can we attempt to reduce to form and law the irregular and agitated movements which are now throwing the whole sea-surface into tumult. Yet even here order reigns. These waves, which give its restless aspect to the sea, are of the class called oscillatory. Mr. Russell's description of them is—that they are gregarious, and of two species, progressive and stationary. It appears that a certain degree of adhesion takes place between a moving mass of air and the water over which it sweeps. The result is, that a certain portion of the water is lifted above the general level of the surface, and an oscillatory movement is thus set up, which, by the continued action of the breeze, is increased in magnitude until waves of considerable dimensions are formed. Waves of this class exhibit a number of interesting phenomena, into which it becomes not our present inquiry to enter. In consequence of perpetual changes in the direction of the over-sweeping current of air, the direction and character of the waves are altered. The configuration of the shores reflects the waves, some in one direction and some in another, and new lines of movement are thus awakened. Frequently, also, there are on the sea three or four series of co-existing waves, each series having a different direction from the other, and the individual waves of each remaining parallel to each other. Thus,

the primary appearance of order is lost by the substitution of another sort of order. The velocity with which wave succeeds to wave varies in a heavy sea; waves have been found running at the rate of upwards of twenty-six nautical miles an hour. Captain Stanley has described an ingenious method by which he marked the speed of waves in a heavy sea, with the ship running before the wind. He caused a spar to be veered astern by the marked lead-line, until the spar was on the crest of one wave, while the ship's stern was on the crest of the preceding one. In order to ascertain the speed of the sea, the time was noted when the crest of the advancing wave passed the spar astern, and also when it reached the ship. By a little calculation the speed of the advancing wave could be easily ascertained.

The height of waves, in moderate weather, is insignificant. Near shore they assume a greater degree of curvature than at a distance from land, where they are generally long and low. But when the wind rises, their height and magnitude constitute one of the grandest displays of elemental motion and power.

It is considered by some that the utmost elevation of waves, produced by the action of the wind, does not exceed 12 feet. Others state their occasional height at 20 feet.

Few persons can realize the magnificent effect of standing on the cliffs of the west coast of Ireland, and observing the great breakers rolling in from the Atlantic, some of which have been ascertained to dash up to a height of fifty, and occasionally even 150 feet.

In addition to the oscillatory gregarious waves, Mr. Russell describes another class of waves which he calls Capillary. These minute waves are amongst those phenomena which we most frequently see. When the glassy surface of a lake is broken into countless ripples by the influence of a gentle breeze, the wavelets thus produced are capillary waves: they are mere oscillations of the superficial layer of water, extending to a minute depth, and very short in duration. The velocity of the capillary waves is usually about eight inches in a second of time.

An observer, who will study the surface of a sea during the successive stages of an increasing wind from a calm to a storm, will find, in the whole motion of the surface of the fluid, appearances which illustrate these various classes of waves, as well as exhibit the laws of their motion.

A gentle movement of the air, not exceeding half-a-mile an hour, leaves the glassy surface unbroken: mirror-like it reflects the surrounding objects with minute accuracy. Let this movement increase in velocity and a playful zephyr flits across the surface at the rate of about 17 inches a second, or a mile an hour, and the glassy smoothness disappears, but on its departure the surface remains polished as before. By and by this fitful movement of the air becomes regular, and the mirror-like appearance is permanently lost; the surface is covered with countless wavelets, and we have the phenomenon of *capillary waves* produced. Still, any sheltered spot, where the direct action of the wind is not felt, has the same mirror-like surface at first possessed by the whole, for these

waves cease almost instantaneously upon the intermission of the disturbing cause, not being able to travel spontaneously to any considerable distance. The disturbed surface now presents that appearance of blackness which is often the precursor of a storm: this results from the effect of the unevenness of the surface upon the reflection and refraction of light.

The wind rises yet more; the increasing clouds gather blackness, and nature is overspread with a certain indefinite appearance of gloom, which is often the harbinger of a tempest. The movement of the air is now not less than two miles an hour, and small waves begin to rise uniformly, over the whole surface of the water, with great regularity. On the ridges of these, the tiny capillary waves are seen riding; but, as the wind increases, they disappear, and are then found in the hollows between the waves and on their anterior slopes. The true *secondary waves* are now seen heaving their curling summits far and wide over the agitated surface. Beginning at about an inch of amplitude, and two inches in length, they enlarge their dimensions, unite with other waves, are now and then adorned with a crest of foam, and the surface presents the regular appearance of a stormy sea, the waves being of nearly uniform magnitude.

When these waves are now impelled by the wind against the shelving coast, they break on the margin of the shoal, and continue to roll along in the shallow water towards the beach, and becoming transformed into waves of the first order, that is, waves of translation, finally break on the shore. What a beautiful scheme of harmony and order is ours, when we

find that, from the first movement of a ripple, to that of the great waves which thunder upon the coast in elemental power, all these movements of the water are determinate and obedient to law!

From what has been said as to the cause of movements of this kind in water, it will be evident that, could we in any way diminish, or annihilate the adhesion, or friction, between the surface and the current of air which impels it into motion, the movements would in a great measure cease. This can be effected by means of oil. There has been even some question raised as to the supposed effects of oil in calming the waves of the sea, and no doubt its power has been much exaggerated; but it is certain, that pouring oil on the surface, by modifying the adhesion of the water to the wind, has a tranquillizing influence upon the agitated surface.

We must now advert to movements in the waters of a different kind, viz., to those of currents. There are mighty rivers in the ocean, as well as on land. Some currents are merely due to the mechanical action of the wind; others are ascribed to differences of temperature. Thus, the melting of a large iceberg or of an ice-field, would set up, during the whole period occupied in the process, various irregular currents caused by the descent of cold water, while its place is occupied by the lighter and warmer fluid.

The most remarkable and well-defined oceanic current is the Equatorial. The Trade Winds were noticed to have a twofold cause, the high temperature of the Tropics and the revolution of the earth. This great current of water is due to the latter cause,

and in part to the impulse of the Trade Winds which blow in the direction which it pursues for a large part of its course; namely, from east to west. This current is very evident, both in the Atlantic and Pacific Oceans, between the parallels of 30° on each side of the Equator, pursuing an average velocity of from nine to ten miles a day. It is connected with another system of currents called the Polar. The direction of the latter is from the Poles towards the Equator. A flow of water in this direction is induced by two causes. In the equatorial regions, in consequence of the greater power of the solar rays, a vast amount of water is raised into the atmosphere by the force of evaporation; to supply this loss a flow of water sets in from the colder regions lying north and south, and thus a current is produced. In addition, the greater velocity of the earth, at the Equator, tends to draw the water from less swiftly moving regions to that position, and thus also a current is established. That such a current, or system of currents, actually exists, cannot be doubted. The evidence of their existence and power is found in the frequency with which icebergs are found in the navigation of the Atlantic, sometimes as low even as 45°, and even 40° of latitude. It was also provokingly manifested to the boat-sledge expedition of Captain Parry to the North Pole: as they advanced over the fields of ice to the northward, they were actually carried at a quicker rate south by the polar currents which bore upon the ice over which they travelled.

On the polar current reaching the equatorial regions, in consequence of its possessing, owing to its

place of origin, a lesser degree of rotatory motion than the region into which it is now brought, it appears as a current from east to west, and, uniting with the equatorial currents, flows in one broad stream, like a mighty river, half-way across the globe.

The equatorial current striking against the vast continent of America, divides into two great currents. Of these, one flows down the east coast of South America, and enters finally the Pacific Ocean, through the Straits of Magellan. The other turns northwards, enters the Gulf of Mexico, sweeps round the coast in a powerful current, as rapid and well-defined as if it were a great river, and now known as the Gulf Stream, proceeds on its onward course at the velocity of four or five miles an hour. More northward still, this large current of water traverses the coast of North America, sweeps by Newfoundland, passes eastward, and crosses the world again, extending even occasionally to the western coast of the British Isles. After this, it is supposed to bend downwards, along the western shore of Africa, until its widely-circulating waters become once more commingled with those of the great equatorial current from which they originally proceeded.

This remarkable portion of the great circle of oceanic currents receiving a large increase of temperature in sweeping along the shores of tropical America, and particularly in the Mexican Gulf, is distinguished by this increase of temperature from the waters of the surrounding ocean. The entrance into it becomes sensible even to the thermometer; sometimes its temperature is 86°, the waters around being

60°. Its waters are also remarkable for their beautiful indigo blue colour, separating it from the green waters of the Atlantic for hundreds of miles, and for the fogs, which, in its course near Newfoundland, are produced from the condensation of the warm and moist air overhanging it. It is chiefly in the warm waters of this great current that the Gulf-weed is found in long trails; it is a species of Fucus, and is known under the name of *Sargassum vulgare.*

In the wide domains of the water-world other important general currents and countless local currents exist, which have their importance and their cause in the places where they appear.

It seems not unlikely that, deeply concealed from the perception and investigations of man, a number, or even a system of submarine currents exist. We are not to suppose all movement is on the surface. From the singular result obtained by Messrs. Kotzebue and Dupetit Thouars, adverted to in a previous page, it appears not improbable that some system of circulation may be in operation in the lower regions of the ocean. It is even stated that in some parts of the Caribbean Sea, where the upper branch of the equatorial current runs strongly, a boat may be anchored, without the anchor touching the ground, and kept stationary, while the waters on which it floats are sweeping rapidly along. This is effected by lowering an anchor or some similar heavy body down to some depth; it there appears to be impelled or dragged by a current exactly opposite to that on the surface, with sufficient force to neutralize the drifting power of the upper current. Although the particles of water move

much less freely over one another than those of air, it is quite conceivable that extensive submarine currents pass in various directions in the abysses of the ocean as the lower currents of air over one another and over the surface of the land.

With all these movements of the waters, with the tide, the wave, the ripple, and the current, there is a more or less complicated philosophy.

In considering the tidal Chemistry as distinguished from those of the wave, we have chiefly to inquire into the probable effects of a periodic influx and reflux of sea-water upon the objects exposed. This phenomenon exerts a very important influence upon the inorganic constituents of the shore, and also upon the various inhabitants of the sea, vegetable and animal, lying within the line of low-water, or ebb of the tide. On almost all sea-coasts, and particularly on such an one as that we are contemplating, where a river brings down constant supplies of material from a rich alluvial soil inland, there exists a certain amount of organic vegetable and animal matters, which, as is common with all such matters, are extremely prone to decomposition, and are here placed in circumstances peculiarly favourable to it. The ebb of the tide exposes such matters to the full influence of the air, leaving them sufficiently moist to forward the changes which immediately commence in organic matter so exposed. A process of putrefactive decomposition is set up, under the combined and alternate action of water and air, and a definite fixedness of composition is attained by the compounds thus situated, preparatory to their removal and submergence beneath the waters of the great deep.

In our own mild climate these decompositions are so slight, though constant, as to be without any perceptible effect upon the air of their vicinity, and it is well known that the air near the sea-coast is generally highly pure and salubrious. But in tropical countries the case is widely different; the full influence of the sun favours all these decompositions to a fearful extent, and the most subtle and deadly poisons are produced upon the sea-coast.

It was until recently considered that the fearful mortality on the coast of Western Africa was due to the development of sulphuretted hydrogen gas, as a result of the mutual reaction of vegetable matter and the sulphates in sea-water. But this is not the case. Yet in the neighbourhood of Copenhagen the disengagement of sulphuretted hydrogen gas is so large that the silver at suburban places near the shore is deeply blackened by it. But its formation appears to succeed to a sort of fermenting process, produced on the shore by the heat, moisture, and presence of organic matters in the mud. Where in tropical countries the forests come down to the beach, which is covered with thickets of mangroves, where the small tides are sufficient alternately to cover and uncover the roots and parts of the trunks of the trees, there the mud, the dead leaves, and animal matters putrefy, and give rise to fearful poisons; and also assist in the development of sulphuretted hydrogen gas.

Recent investigations by Professor Forchhammer teach that important consequences follow upon the putrefaction even of a mass of sea-weed on the shore.

When this takes place upon a bed of clay containing iron, a series of chemical decompositions is commenced, which results in the formation of iron pyrites, which penetrate the clay. When this is again exposed to the weather it oxidizes, and sulphate of iron is formed.

The return of the tide is the signal to all the marine plants to recommence their duties, and as the waters again sweep over them they acquire new life and vigour, and proceed with their periodical task of decomposition upon the gases held dissolved in the water. By their return also the waters put a stop to such of the chemical changes taking place in the substances composing the coast as require the presence of atmospheric air. Soluble matters in the soil are also dissolved out, and a supply of water, free from the impregnations of the coast, is periodically afforded to all the zoological inhabitants of the shore-zone. The consideration of the varied processes of vital chemistry taking place in the waters is deferred to the next chapter.

As we look to the foaming edge of the waters now rolling at our feet, and contrast its colour for several yards off shore with the purer and more transparent tint of the waves at a greater distance, we immediately become sensible of the fact that with every tide certain mechanical effects, of greater or less amount, must be produced upon the materials composing the shore. These heavy billows, which break so unceasingly on the beach, creating that peculiar sound, well described as the "voice of many waters," in so doing churn up all the loose materials in their track, and

violently agitate and dash them one against another. The power of water, in thus destroying by its mechanical effects the most solid masses of rock, is wonderfully great, and this not only in its sum, but in each individual effect. Near Kilkee, on the west coast of Ireland, exposed to the buffeting of the long and

ROCKS NEAR KILKEE.

mighty waves of the Atlantic Ocean, their effects are most remarkable. In consequence of peculiarities in the chemical composition of the strata some parts are more easily acted upon than others, and the resisting portions consequently stand out in relief and present the most grotesque appearances. The most curious resemblances of pillars, bridges, and porticos, appear

as the evidence of the destructive power of these waves. Here and there we might imagine that we beheld a vast cathedral in ruins; the pointed arch is there, but the fretted aisle and stately pillar are not. The roaring music of tumultuous waters forms the harmony of these natural temples, and the congregation, crowds of sea-birds screaming to their young, which line the shelf-like projections on the cliffs.

GRIND OF NAVIR.

Dr. Hibbert gives an animated description of the effects of these great billows upon certain parts of the rocky coast of the Shetland isles:—"The most sublime scene is where a mural pile of porphyry, escaping the process of disintegration that is devastating the coast,

appears to have been left as a sort of a rampart against the inroads of the ocean. The Atlantic, when provoked by wintry gales, batters against it with all the force of real artillery, the waves having in their repeated assaults forced themselves an entrance. This breach, named the Grind of Navir, is widened every winter by the overwhelming surge that, finding a passage through it, separates large stones from its sides, and forces them to a distance of no less than 180 feet. In two or three spots the fragments which have been detached are brought together in immense heaps, that appear as an accumulation of cubical masses, the product of some quarry." Mr. Stevenson states that, during the erection of the Bell-rock Lighthouse, such was the force of the waves, that drift-rocks, measuring upwards of thirty cubic feet and more than two tons in weight, have during storms been thrown upon the rock from the deep water which surrounds it.

Almost the whole coast of Yorkshire from the Tees to the Humber is being gradually destroyed by the action of the sea. "In the old maps of Yorkshire," observes Sir C. Lyell, "we find spots, now sand-banks in the sea, marked as the ancient sites of the towns and villages of Auburn, Hartburn, and Hyde." "Of Hyde," says Pennant, "only the tradidition is left, and near the village of Hornsea, a street called Hornsea Beck has long since been swallowed." In one place on the coast of Norfolk, there was at one point in the harbour, in 1829, a depth of 20 feet, sufficient to float a frigate, where only forty-eight years before there stood a cliff, 40 feet high, with houses upon it!

When we come to inquire into the Chemistry concerned in this process of destruction, it will be manifest that it must greatly vary with the nature and character of the sea-coast. Yet the grand chemical operations of nature are all carried on in a remarkably simple manner, and we find that water, carbonic acid, and atmospheric oxygen are, as in the waste carried on inland, the chief agents of destruction. The hard granitic rocks of the northern isles cannot withstand the influence of carbonic acid acting upon them in a state of solution, and constantly applied to their surface by the dashing upwards of the waves. Wherever the spray touches them they begin to feel the slow but certain influence of the process of decay. Rocks of all varieties of composition—serpentine, porphyry, clay-slate, gneiss, limestone, granite—all waste under the gentle touch of the air and foam, and become thus prepared to submit to the force of the overwhelming surges which at times are cast upon them. The soluble portions of the rocks, thus exposed, become separated and dissolved out by the waves, the surface loses its solidity and compactness, and may be found on examination covered for some inches in depth with a layer of disintegrated matter, which only awaits the coming of the first tempest to be torn off and borne away by the triumphant waters to the depths of the sea. While the water itself is not without a solvent action on all rocks, yet it is the oxygen and carbonic acid gases, held in solution by the waves, which are most instrumental in effecting this process, and those portions of the rocks which are submerged, although less influenced than the parts

exposed to the air and consequently to greater vicissitudes of temperature, are nevertheless gradually destroyed by these means.

The matter thus produced accumulates at the base of the cliffs, and it may be observed forming a sort of low mound at their foot along the rocky portions of the coast, there to remain, however, only for a time. This leads us, therefore, to ask what becomes ultimately of this disintegrated matter? "The current which flows from the north-west," remarks Sir C. Lyell, "and bears against the eastern coast of England, transports materials of various kinds. Aided by the winds and waves, it undermines and sweeps away the granite, gneiss, and trap-rocks and sandstone of Shetland, and removes the gravel and loam of the cliffs of Holderness, Norfolk, and Suffolk, which are between fifty and two hundred feet in height, and which waste at the rate of from one to six yards annually. It also bears away, in co-operation with the Thames and the tides, the strata of London clay on the coast of Essex and Sheppey. The sea at the same time consumes the chalk with its flints for many a mile continuously on the shores of Kent and Sussex, commits annual ravages on the fresh-water shells, capped by a thick covering of chalk-flint gravel, in Hampshire, and continually saps the foundations of the Portland limestone. It receives besides, during the rainy months, large supplies of pebbles, sand, and mud, which numerous streams from the Grampians, Cheviots, and other chains send down to the sea. To what regions, then, is all this matter consigned? It is not retained in mechanical suspension by the

waters of the ocean, nor does it mix with them in a state of chemical solution: it is deposited somewhere, yet certainly not in the immediate neighbourhood of our shores, for in that case there would soon be a cessation of the encroachment of the sea, and large tracts of low land, like Romney Marsh, would almost everywhere encircle our island."

The sediment, producing the line of discoloration to which we have alluded, is extremely fine. Wheresoever transported, of its ultimate deposition there can be no doubt. The bed of the ocean is being constantly overlaid with such matters, accumulating from age to age, though with such slowness as often to defy detection. Shells and marine creatures of various kinds are becoming embedded in it, and in process of time it may become dry land again, adorned with vegetation and the habitations of men and animals.

In connection with the combined mechanical and chemical forces, the cliffs on the coast of Ballybunnion may serve as an illustration. Large caverns, natural bridges, and the resemblances of human architecture abound on the sea-coast, being produced by the unequal wasting away of different strata. The roofs of these caverns are painted with various hues by the water percolating the overlying strata, and carrying with it a solution of the mineral ingredients encountered in its passage. Streamlets also run down the sides of the cliffs, staining them in ochreous colours, proving that the water contains iron, and probably other salts in solution. These solutions are conveyed into the sea, and there undergo various

decompositions in contact with the saline matter of sea-water. Some years since part of these cliffs assumed an appearance of a very extraordinary character: the waves by continual dashing had worn and undermined the cliff, which, giving way, fell with tremendous violence into the sea; the consequence was, that several great strata of pyrites were exposed to the chemical influence of the air and sea-water; rapid oxidation took place, eliminating such an intense heat as very shortly to set the whole cliff on fire. For days the great rocks continued burning with much fierceness, torrents of steam and smoke rising up as the heavy billows of the Atlantic leaped upon the glowing masses, and at a distance presenting all the appearance of some violent volcanic disturbance. After the fresh substances thus exposed had become oxidized, the steaming cliff gradually cooled down; and now the slow and silent work of mechanical and chemical destruction is being carried on without any external manifestation of its existence. The heat given out during this singular and grand chemical phenomenon was so great as to convert masses of clay in its vicinity into red brick; while the melted slags which lie about, give to the whole scene such an appearance, as to render it a fit representation of the workshop of the mythological Cyclops.

From what has been already said upon the Chemistry of the sea it will be evident that the solution of the gas oxygen, in water, is of the utmost importance to the marine inhabitants. Much of this oxygen, as we shall yet have to notice, is obtained by vital processes; but, as we look along

the shore, white with the foam of countless waves, as we remember the intimate manner in which air is thus mingled with water, and reflect upon the incessant continuance of the same phenomenon, can we doubt that, in the same manner also, a large quantity of this valuable ingredient is added to the waters for the service of the inhabitants of the sea? In consequence of the slight solubility of oxygen in water the process is slow, and the result accomplished in a given time is small. But, listening to the unceasing roar of wave upon wave, remembering that night and day this continual agitation is maintained, can it be said that, with such means, and so continued, a great result is not both attained and perpetuated? And when we consider the large number of marine creatures which abound, especially near our shores, it does not seem improbable that this is one of the means by which the purity of the waters is sustained. The effect of storms at sea, particularly when cross seas are produced, is no doubt similar, and the same object may thus be accomplished.

The last point remaining for consideration, in the philosophy of the movements of the waters, is that of currents, and their chemical phenomena. One great function fulfilled by these ocean streams is the equalization of the temperature of the ocean, and the communication of their temperature to the shores along which they roll. The waters of the great Gulf Stream carry heat with them along the banks of Newfoundland, as high into the northern regions as to Spitzbergen, where they are supposed to set free great icebergs, by melting their bases; and as the

stream flows down the western coast of Europe, it communicates the remains of its tropical warmth to countries, between which and the source of heat in the current, lies the broad bosom of the great Atlantic. The polar currents, on the contrary, pour their cold waters upon the heated shores of the burning tropics, thus mitigating the intensity of their temperature, and communicating a grateful coolness to regions otherwise comparatively intolerable.

It has been before mentioned that there is a notable difference with regard to the amount per cent. of their saline ingredients in the waters of the tropical seas and of those lying more to the north, in consequence of the greater amount of evaporation suffered by the former, compared with the latter. A current, therefore, setting out from tropical regions and extending to the Polar seas, will convey its high charge of saline matter with it, and throughout its track. On the other hand, a current setting out from the Poles, will carry with it water, less charged with saline contents. By this means a perpetual circulation of these ingredients is maintained, and a considerable degree of uniformity in the composition of ocean-water is secured. The importance of these two classes of duties, fulfilled by marine currents to the preservation of an uniformity of temperature and composition in the whole, can scarcely be exaggerated; and there can be little doubt but this grand system of ocean circulation has a most intimate connection, not only with the inhabitants of the land, but with the well-being of the varied tribes which people the sea.

Imperfect as is our knowledge of the chemical phenomena connected with the movements of the waters, these few considerations may serve to indicate the interesting character of the subject, and to stimulate fresh inquirv.

CHAPTER IV.

LIFE IN THE WATERS.

It is a reflection calculated to awaken feelings of interest to remember that the world of waters is not a blank, but is tenanted with animals and plants, and is the scene of as much bustle of life as is the earth, or the air. On descending to the shore and investigating matters a little more closely, we are made conscious of the number, beauty, and variety of the marine inhabitants. The chemical connection of these with each other, and with the water in which they dwell, will form the subject of the present chapter.

"We find the vegetation of the ocean, no less conspicuous for beauty and variety of form, than splendour of colour, admirably fitted for the place it is designed to occupy, and of direct utility to mankind. The marine alga is no longer the *Alga inutilis*—(the worthless alga). Viewing these tribes in the most careless way, as a system of subaqueous vegetation, or even in a merely picturesque light, we see the depths of the ocean shadowed with submarine groves, often of vast extent, intermixed with meadows, as it were, of the most lively hues; while the trunks of the larger species, like the giant trees of the tropics, are loaded with innumerable minute kinds as

fine as silk, or transparent as a membrane. Nor must we forget, that while thousands and tens of thousands of quadrupeds, birds, and insects, depend upon the vegetation immediately surrounding us for their very existence, a countless host of creatures derive protection and nourishment from the plants of the deep. Some of the Algæ, placed, on account of the comparative simplicity of their structure, at the bottom of the scale, are so small as to be invisible to the naked eye, except by the appearance they give to other species on which they happen to be parasitic in prodigious numbers. From these microscopic forms, Algæ are found, of all sizes, on our own shores, up to thirty or even forty feet in length, an extent to which *Chorda filum* not unfrequently attains. This plant resembles an enormous piece of catgut, and is, in fact, known by the name of *Sea catgut* in Orkney, while in Shetland it goes by the name of *Lucky Minny's lines*, and in England of *Sea lace.*" (Greville's "British Algæ.") In the southern hemisphere the marine vegetation presents a more wonderful aspect. A plant described by Bory St. Vincent, is twenty-five or thirty feet high, and has a trunk often as thick as a man's thigh, which divides into numerous branches. A marine plant, abundant on the Australian coast, furnishes the aborigines with instruments, vessels, and food. A trumpet is formed out of the hollow stem of another.

Some of these plants remain constantly beneath the surface of the waters, their roots firmly attached to rocks or stones at the bottom. Others float on the surface, presenting the appearance of green meadows,

reposing upon the ever-moving breast of the wave. Near the coast of California these plants grow in such thick masses as to have saved vessels from the danger of being driven ashore by the long and heavy swell of the Pacific. They are supposed to grow without attachment to any rock, carried about by the waters which bear them and supply them with all that is necessary to their existence. In the tropics, where the waters are singularly pure and pellucid and the light very powerful, it is often a splendid spectacle to look down over the ship's side and contemplate the beautiful vegetation adorning the sea-bed.

But there exists a limit to the vegetation of the sea, beyond which it is unable to pass. The dark bottom of the deep ocean is a water desert, unenlivened with a single species of plant. Thousands of miles in area of the bed of the waters are thus waste and barren. Professor Forbes, in his dredging researches in the Ægean Sea, found no plants below 100 fathoms. A more singular part of their history is, that they are distributed in zones, at various depths and degrees of removal from light and warmth. The first zone is the space included between high and low water mark. It is occupied by distinct species of sea-weeds, many of which are well known to the frequenters of our English watering-places. The second zone on our coast, beginning at low-water mark, extends below it to a depth of from 7 to 15 fathoms. This also has its peculiar vegetable inhabitants. The great sea-tangle luxuriates here, together with broad-leaved *Fuci* of various kinds. The last plant of this zone is the *Nullipora*, a coral-like sea-weed, the lowest

in the British seas, where it does not extend below the depth of 60 fathoms. In the Mediterranean Sea Professor Forbes has found *Fuci* at a depth of 79 fathoms; below this they altogether disappeared. *Nullipora*, so curiously resembling coral as to have been long mistaken for an animal rather than a vegetable production, still exists in that sea, forming the food of various marine creatures, at a depth of 105 fathoms. Below this, vegetable existence ceases. In all seas it will probably be found that a similar system of order and arrangement prevails. In the Mediterranean, as the depth increases, the number of the plants becomes fewer; until just before the depth of 105 fathoms, the traces of submarine vegetable life are very scarce indeed.

Until recently, it was thought that the sea-weeds known under the botanical titles *Macrocystis pyrifera* and *Laniaria radiata*, which have been met with on the antarctic coasts, formed the utmost limit of vegetable life in the south polar seas. Beyond the region in which these plants were found, it was supposed that the ocean and land were alike barren of vegetable forms. But an interesting account has been given by Dr. Hooker of a peculiar class of vegetable organisms, discovered between the parallels of 60° and 80° south, which proves that, at the icy regions of the poles, vegetable life is still to be found. This singular vegetation occurred in such countless myriads as to stain the sea everywhere of an ochreous brown colour, in some cases causing the surface of the ocean, from the locality of the ships as far as the eye could reach, to assume a pale brown tint. Though peculiarly

abundant in the Icy Sea, these plants are probably uniformly dispersed over the whole ocean, but being invisible from their minuteness, they can only be recognised when washed together in masses, and contrasted with some opaque substance. While the species of these plants were found to increase in number with the latitude, up to the highest point attained by man, they were also found by Ehrenberg in both Americas, in the south of Europe, and north of Africa, in a fossil state, and even in volcanic ashes. Their remains have been found floating in the atmosphere, overhanging the tropical Atlantic; for Mr. Darwin, during the voyage of the *Beagle*, collected an impalpable dust which fell on Captain Fitzroy's ship, when to the west of Cape De Verd Islands, and it proved, on examination, to consist of remains of these plants, including species common in the antarctic regions.

This vegetation forms undoubtedly the food of many of the countless marine tribes peopling the antarctic waters, and which are subsequently themselves a prey to larger creatures. They were invariably found in the stomachs of sea animals, in all latitudes between that of the north tropic and the highest parallel attained by the antarctic expedition. Guano, too, the excrement of sea-birds, contains the hard parts of these curious and beautiful forms in countless numbers. The death and decomposition of this antarctic vegetation are gradually producing a submarine deposit, or bank, of vast dimensions. This bank consists mainly of the silicious coatings of the cells, intermixed with infusoria and inorganic matter.

Its position is from the 76th to the 78th degree of south latitude, and between the meridians of 165° east and 160° west longitude; thus occupying an area of 400 miles long by 120 wide. All the soundings taken over this deposit brought up the finest green mud, mixed with sand occasionally, from the depth of between 200 and 400 fathoms. The lead sometimes sank 2 feet into this pasty deposit.

Let us now inquire how is this marine vegetation nourished, and what are the functions which it discharges. Just as when wood is burnt, an ash remains, so also when sea-weed is similarly treated. In spring, the deep sea-tangle on the north coasts of France and Ireland and the western coasts of Scotland is collected, dried during the summer and burnt in large heaps. The ash thus obtained is called kelp, and it is employed especially for the sake of the iodine which it contains. The sea-weed extracts iodide of sodium from the water, and gives an insight into the constituents of the ocean which nothing else could furnish. The chemist can only detect minute traces of iodine in sea-water, yet he extracts it from sea-weed with facility.

Another constituent of sea-water is bromine. After evaporation, crystals of common salt are obtained, and in the so-called "mother-liquor" the bromide of sodium is found. Chlorides, bromides, and iodides are found in the ashes of sea-weeds, and these are contained in the sea; so are also the sulphates and phosphates, as well as the earthy carbonates. We may refer the reader to the analysis of sea-water for most of the mineral ingredients; but what is the

origin of the carbon in sea-plants? Just as in terrestrial plants, the source of the carbon in sea-plants is the carbonic acid of the medium which surrounds them. Sea-water, in common with all water in a state of nature, contains a certain quantity of this gas in a dissolved state: it is derived from the respiration of fishes and other of the marine tribes, and from a number of chemical processes constantly taking place in the constituents of vegetable matter. Carbonic acid is present in sea-water in larger quantities, even, than in the air: in 10,000 volumes of sea-water, 620 volumes of this gas have been found. By taking a piece of a living sea-weed and preserving it in a basin of sea-water, it will, by the oxygen it gives out, keep the water sufficiently fresh, to enable various little marine insects to live in it for some time. The singular plants, called corallines, about which so many erroneous views have been entertained, on the supposition that they were animal in their nature, and which occupy so large a tract of the sea-bed, possess this function in common with the rest of the vegetable inhabitants of the waters. Dr. Johnston performed an interesting experiment upon these plants, which pleasingly illustrates their utility, minute and feeble though they appear in the great waters by which they are surrounded. He placed in a small glass jar, containing about six ounces of clear sea-water, a tuft of living coralline, about the branches of which several little mussels and other animals and a star-fish were crawling. The jar was placed on a table, and was seldom disturbed, though occasionally looked at, and at the end of four weeks the water was still fresh, the

little animals all alive and active, and the plant had grown sensibly larger. At the expiration of eight weeks the water continued pure, and many of the animals were living. Had the coralline not been there, a day would have sufficed for the animals to have extracted all the oxygen of the water, and in a week, or two, the water itself would have commenced the changes of putrefaction. Nothing could more conclusively exhibit the effect of plants upon the waters of the ocean, for here was a sea in miniature, the animal producing carbonic acid, and the coralline absorbing and decomposing it, and then emitting its oxygen. With some slight additional means of purifying the water and of checking the extravagant growth of confervæ, the plan of thus balancing the vegetable and animal actions, is seen in that beautiful contrivance, which has already revealed so many of the marvels of the deep, the marine aquarium.

Calling to memory the wonderful facts elicited from the Chemistry of the sunbeam, and its connection with vegetation, the inquiry naturally arises, whether the vegetation of the deep is as dependent as that of the land upon the various energies of the solar ray? Direct experiments, of a trustworthy character and sufficiently numerous, are yet wanting to determine this point; but it is found that vegetation generally ceases at such depths as mark the extinction of the solar ray. The light received by these plants is of a greatly diminished intensity. Many of them must live in little better than an alternation of twilight and night. Even those which occupy the littoral region, must enjoy much less of the power of the sun's ray,

than the humblest plant dangling on the rock in mid-air. The actinic and the luminous rays of light are those which appear chiefly to influence the marine vegetation: in what way it remains for us to learn. Enfeebled though the solar influences may be by their passage through the water, they suffice to quicken the plant, and to enable it to sustain an active existence. We are apt to imagine that sea-weeds are very slow in growth, but this is, in the case of many of them, an error; a few months sufficing to cover rocks with plants which had before been perfectly clean and bare. The sea-weed, low though it is in the order of vegetable creation, and insignificant as it appears in our eyes, is beautifully adapted to the place of its abode.

As in the air, so in the water of the sea, ammonia may be detected, and is also the chief source of the nitrogen contained in such plants: it originates in the death and decomposition of plants and animals.

The marine vegetation acts a part, with reference to the preservation of the constancy of composition in sea-water, not less beautiful and interesting than the decomposition of carbonic acid by plants growing in the air. The sea is not less exposed to the risk of deterioration than the air. The sources of its gaseous deteriorations and their remedies have just been noticed. But in every shower falling on the land, washing out certain mineral ingredients, and by various channels directing them into the great receptacle, we may perceive a large source of impurity, and the question comes to assume a great importance, when we note, by what means the otherwise inevitable

consequences of these additions to the mineral constituents of sea-water are to be averted. The provision to this end is to be found in the varied tribes of marine plants. It will be most evident what fixed or inorganic ingredients these plants appropriate and separate, if we examine the character of their ashes.

If, however, sea-weeds merely separated these ingredients for a short time, and when they died if they were again to return to the sea-water, their effect in preserving its constant composition would be inconsiderable. Such is not the case. When these plants die they are cast by the waves upon our shores in vast heaps. Thus, in various ways, a great part of the ingredients separated by sea-weeds from sea-water is removed from it in such a manner, that they have to perform many functions and to wander much, before they can be restored to it again.

The ocean is very much more prolific in animal, than even in vegetable life. From the minute infusorial animalcule, imperceptible to the unaided eye, up to the whale, all varieties of size and form are found. Of the numbers of the more minute creatures language can convey no idea. Just as the vegetation noticed by Dr. Hooker, by its numbers coloured the waters of the Antarctic Ocean, so, minute animated creatures abound in the arctic seas, turning the ultramarine blue of the waters to a turbid green. The bodies of these animalcules are exceedingly small, yet they are found discolouring patches many miles square, and of great depth. To afford some conception of their numbers, Scoresby

has made the statement, that in the space of two square miles, supposing the animalcules to exist as low down as 1,500 feet, there would be congregated a mass of individual beings, which eighty thousand persons would not have been able to enumerate, though they commenced the task at the Creation and continued it incessantly to the present time. Yet this would prove but a very small portion of the entire sum of these beings existing at one time in these seas! Ehrenberg, after examining various specimens of sea-water sent to him by Sir J. C. Ross, states that in high "southern as well as in high northern latitudes, and at great ocean depths, the minute forms of organic life are intensely and extensively developed." Near Franklin Island a great quantity of ice of a brown colour was observed. The colour was entirely due to innumerable hosts of these minute organized beings. Samples of water have been taken up in various latitudes, and on accurate microscopic investigation, innumerable, extremely minute, organisms have been detected, floating generally in a fragmentary state. Thus, even in the perpetual night of the depths of the ocean, animal life abundantly exists, though of a low type.

"On the coast of Chili," remarks Mr. Darwin, "a few leagues north of Concepcion, the *Beagle* one day passed through great bands of muddy water, exactly like that of a swollen river; and again, a degree north of Valparaiso, when fifty miles from land, the same appearance was still more extensive. Some of the water, placed in a glass, was of pale reddish tint; and examined, under a microscope, was

seen to swarm with minute animalcules darting about, and often exploding. They were exceedingly minute, and quite invisible to the naked eye, only covering a space equal to the square of the thousandth of an inch. Their numbers were infinite; for the smallest drop of water which I could remove contained very many. In one day we passed through two spaces of water thus stained, one of which alone must have extended over several square miles. What incalculable numbers of these microscopical animals! The colour of the water, as seen at some distance, was like that of a river which has flowed through a red clay district; but under the shade of the vessel's side it was as dark as chocolate. The line where the red and blue water joined was distinctly defined. The weather for some days previously had been calm, and the ocean abounded to an unusual degree with living creatures."

The exploration of the bottom of the sea has been carried on in every part of the world, and since the results of the expedition of H.M. ship *Challenger* much more is known. The ocean floor is being gradually raised by the labours of almost invisible agents, and the proverb, "many a little makes a mickle," receives a wonderful illustration. It is almost uniformly covered with "ooze," a mud of cream colour or grey. When dried it looks like chalk, but it is not composed of carbonate of lime alone. Under the microscope each separate particle is seen to consist of several globular chambers, one of which is smallest and one largest, while the others are of intermediate dimensions, disposed around a

common centre and adherent. Each chamber has an opening in the face which is turned towards the centre. In the living state, all the chambers are filled with a jelly-like substance, which spreads over the surfaces of the chambers and sends out long radiating contractile threads. The walls are hard and brittle from the calcareous matter present; in the smaller chambers they are very thin and quite transparent. In specimens, taken from the sea with great care, the outer surfaces of the chambers are beset with long slender calcareous processes, like threads of glass; but these very readily break off. "The bodies thus described," says Professor Huxley, "are the skeletons of animals of a very simple character, known as *Globigerinæ bulloides*, belonging to the group *Foraminifera* (from *foramen*, an aperture, and *fero*, I carry), in consequence of the numerous perforations usually visible in their hard parts."

The investigations of the *Challenger* have now placed it beyond doubt that, whether any of the Foraminifera live at the bottom or not, they certainly swarm in prodigious numbers at and a few fathoms below the surface. They were taken by the tow-net in all latitudes, over an area extending for between 50° and 60° on both sides of the Equator; and though they abounded most in warm and temperate climates, they were not entirely absent towards the northern or the southern limits of this range.

In addition to the calcareous organic remains which constitute the greater part of the ooze, it contains multitudes of siliceous skeletons, some of which belong to simple animal forms, such as *Radio-*

laria and the Sponges, while others are vegetable organisms, belonging to the group of *Diatoms*. The *Diatoms* and the *Radiolaria* inhabit the surface of the ocean, along with the *Globigerinæ* and *Orbolinæ*, but the Sponges live at the bottom. Here and there the remains of other animals which inhabit the depths of the sea, such as Star-fishes, Sea-urchins, and various shell-fish, are also embedded in the ooze, and contribute to the solid submarine deposit. (Huxley.)

While a considerable number of the dwellers in the deep feed upon the vegetation with which to a certain depth it abounds, a yet greater number prey upon their fellow-occupants of the waters. In consequence of the limits to which marine vegetation extends, it would not have sufficed to sustain the wants of the countless millions of marine beings had they been confined to a vegetable diet, or had the proportion of predacious and herbivorous creatures been, in the deep, as it is on land, where vegetation almost everywhere abounds. Hence, in the ocean generally, and in the polar seas in particular, where the vegetable kingdom which constitutes the support of animal life in milder climates has no representative if we exclude the minute plants before mentioned, a chain of animal existence has been constituted, which as effectually completes the great intention of the preservation of life, as that regulating the life of animals on land. Creatures of a higher order prey upon those of a lower, and these again upon those next below them in the scale of created beings, which in their turn

feed upon the innumerable infusorial animalcules thronging the ocean.

The vital function in marine creatures generally, with which the Chemistry of the ocean is chiefly concerned, is that of respiration. Although not living in the air, these creatures breathe, and oxygen is as necessary to them as it is to ourselves. Now Chemistry informs us that 100 parts by measure of water will only dissolve at most three parts by measure of oxygen: and yet this small proportion is sufficient for the well-being of marine creatures. Had oxygen been very soluble in water there would have arisen many bad results to the animal world on land, and not less to those of the waters themselves. The effect upon the inhabitants of the deep of a higher charge of oxygen in their respirable medium would be precisely analogous to its effects upon air-breathing creatures; and the loss to the latter, from the vast amount of oxygen thus removed from the atmosphere, might have been beyond the power of the most profuse vegetation to repair. Although sea-water contains nitrogen in solution, as well as oxygen, yet its proportion is only small, and we may regard the water as the diluent for oxygen in the ocean, as nitrogen is for it in the atmosphere.

The manner in which the dissolved oxygen is received by fish, from the medium in which they live, is very similar to that in which air-breathing creatures receive it from the air. In the gills and other modifications of the respiratory organs in marine beings, there exists a similar provision for the exposure of the blood to the influence of oxygen, as in those of air-

breathers. The gills are composed of numerous *laminæ*, or plates of tissue, covered with innumerable minute blood-vessels, and exposing a very large surface to the influence of the oxygen dissolved in the water. The water becoming partially deprived of its dissolved oxygen, is discharged from under the gill-covers, a fresh portion being taken in at the mouth. Thus a continual current of fresh water is caused to flow over the laminæ, from which a constant supply of oxygen is obtained by the fish. The blood, after becoming thus oxygenated, is further propelled by the heart throughout the body of the creature, and, losing its oxygen in the capillary vessels, returns by the veins to undergo the same process again. In so doing, the venous blood parts with carbonic acid, which is received and retained by the surrounding fluid in a dissolved state. The temperature of fishes is generally two or three degrees higher than that of the water in which they live. These facts render it apparent, that it is not less important to the residents of the waters, than to ourselves, to be provided with a full and free supply of oxygen, and explains the cause of the death of fish when placed in a limited quantity of water, even though the water may not have undergone any sensible change. When fish are thus placed, and have exhausted the stock of dissolved oxygen in the fluid, they rise to the surface, and swallow atmospheric air, the oxygen of which becomes then subservient to their uses. This can rarely occur in a state of nature, but it is constantly seen when fish are kept in small artificial receptacles. It is a most common and

painful sight to witness this action in gold-fish, kept within the too narrow confines of a glass globe, where, if no vegetable life is present, not only is the oxygen consumed, but carbonic acid accumulates.

The effect of the respiration of fish and of the presence of other marine inhabitants upon the waters in which they live, is similar to that of man and air-breathing creatures generally, upon the atmosphere; the fluid becomes vitiated, and a necessity is created for its renewal. This process, as in the terrestrial world, is, as we have seen, discharged by plants. There can be little doubt also, that the mere effect of constant agitation, as before noticed in the phenomena of waves, causes the solution of a large portion of oxygen; for it is found that sea-water contains also nitrogen in solution, which has unquestionably been obtained from the agitation of water and air together. The oxygen in the rain which falls on the sea, is likewise an important addition to its contents. We may, indeed, perceive in the grand circle of the evaporation of water from the sea, of its condensation in largest quantity over land, and of its return by innumerable channels to its vast reservoir, a beautiful system of providing for the due oxygenization of the ocean waters, although this circulation effects, in addition, many other and scarcely less important results. For no method of dissolving atmospheric oxygen could be devised more complete than this. Rapids and cataracts effect a similar object. Could the chemist draw from the foaming pit of water, into which the waterfall at the other end of this valley leaped, a sufficient amount to submit to analysis

tor its gases, and were he to contrast it with a similar quantity taken before the leap, he would discover in the former more dissolved atmospheric air than in the latter, unless, perchance, the water had been already saturated with this gas. These processes aid the oxygenization effected by marine plants; but when we consider the comparative smallness of the number of these plants, together with the fact that a large number of them are for some hours, out of every day, incapacitated for their office by the departure of the tides, and that probably these, and a still larger number which live always in deep water, are also unable to fulfil it during the hours of darkness, it will be understood that the relation subsisting between the ocean and its vegetation is far inferior in importance to that subsisting between the air and plants. Considering the vast preponderance of animal over vegetable life, in the ocean, it becomes more than questionable whether the marine vegetation could, unassisted, preserve the purity of the waters, as a respirable medium.

There remains another portion of the Chemistry of the ocean, in its connection with animal life, which requires further elucidation. The *Foraminifera* have been already mentioned, and they derive from the waters the solid matter of which the skeleton is composed. But the shells of numberless molluscous animals, the hard shields of countless millions of animalcules, and the solid substance secreted by the coral animal, are all derived from sea-water by the processes of vital Chemistry. This hard matter consists chiefly of carbonate of lime. It was found

in the researches in the Ægean Sea, that a most important influence was exercised by the composition of the coast and sea bottom. Great tracts of a cretaceous limestone border the sea, and, by their constant disintegration, fill its waters with a white sediment of carbonate of lime. In such water, therefore, those creatures which require this substance for the purposes of their economy may be expected to abound and accordingly, it was found that large numbers of molluscous animals existed in these regions. On the contrary, where the islands and coast consisted of serpentine, the waters bathing them were almost devoid of molluscous or testaceous animals, owing doubtless to the comparative absence of the necessary mineral constituents of the sea-water.

Some idea may be formed of the vast extent of this operation, in the separation of the salts of lime from the waters of the ocean, when it is stated, that the solid limestone rocks of our own and other countries, are often visibly made up of the relics of animals possessing this peculiar faculty; and it appears probable that all limestone, with some exceptions of small moment, were thus obtained by the slow, but perpetual process of the separation of the salts of lime from a state of solution in sea-water. Professor Forchhammer states the remarkable fact, that, in the coral seas, the proportion of lime is much less than in other waters.

The coral formations, however, strike us as the most surprising result of the slow but ceaseless operations of vital Chemistry upon the constituents of sea water. Writing of Keeling Island, Mr. Darwin says "I am glad we have visited these islands; such formations surely rank high among the wonderful

objects of this world. Captain Fitzroy found no bottom with a line 7,200 feet in length, at the distance of only 2,200 yards from the shore; hence this island forms a lofty submarine mountain, with sides steeper than those of the most abrupt volcanic cone. The saucer-shaped summit is nearly ten miles across: and every single atom, from the least particle to the largest fragment of rock in this great pile, which, however, is small compared with very many other lagoon islands, bears the stamp of having been subjected to organic arrangement. We feel surprised when travellers tell us of the vast dimensions of the Pyramids and other great ruins; but how utterly insignificant are the greatest of these, when compared to these mountains of stone accumulated by the agency of various minute and tender animals! This is a wonder which does not, at first, strike the eye of the body, but, after reflection, the eye of reason."

Upon the outer shores of these lagoon-like islands a great surf continually breaks, strewing the solid flat of dead coral rock with huge detached fragments. Yet the little creatures build on. The long and massive swell of the ocean incessantly dashes with immense force upon the outworks of the fragile coral builders. "It is impossible to behold these waves without feeling the conviction that an island, though built of the hardest rock, let it be porphyry, granite, or quartz, would ultimately yield and be demolished by such a power. Yet these low and insignificant coral islets stand and are victorious; for here another power, as an antagonist, takes part in the contest. The organic forces separate the atoms of carbonate of lime, one by one, from the foaming breakers, and

unite them into a symmetrical structure. Let the hurricane tear up its thousand huge fragments, yet what will that tell against the accumulated labour of myriads of architects, at work night and day, month after month? Thus do we see the soft and gelatinous body of a polype, through the agency of the vital laws, conquering the great mechanical power of the waves of an ocean, which neither the art of man nor the inanimate works of nature, can long resist."

On the east coast of New Holland a reef has been described as being one thousand miles long, and, in one portion, is unbroken for a distance of between three and four hundred miles! According to Mr Darwin, coral-rock has been originally formed in water not deeper than twenty fathoms. When found at greater depths, it must have been carried down by subsidence of the rocky foundation on which the polypes lived and died. The labours of these coral animals have added no insignificant mass of solid material to the great earth itself. Yet among the ingredients of sea-water, from whence every particle was probably procured, carbonate of lime exists in but small proportion. In order to add one pound of carbonate of lime to these structures, a quantity of sea-water, not much less than sixty thousand pounds, must submit to the processes of vital chemistry. How forcible an illustration of the real importance of things apparently insignificant!

THE END.

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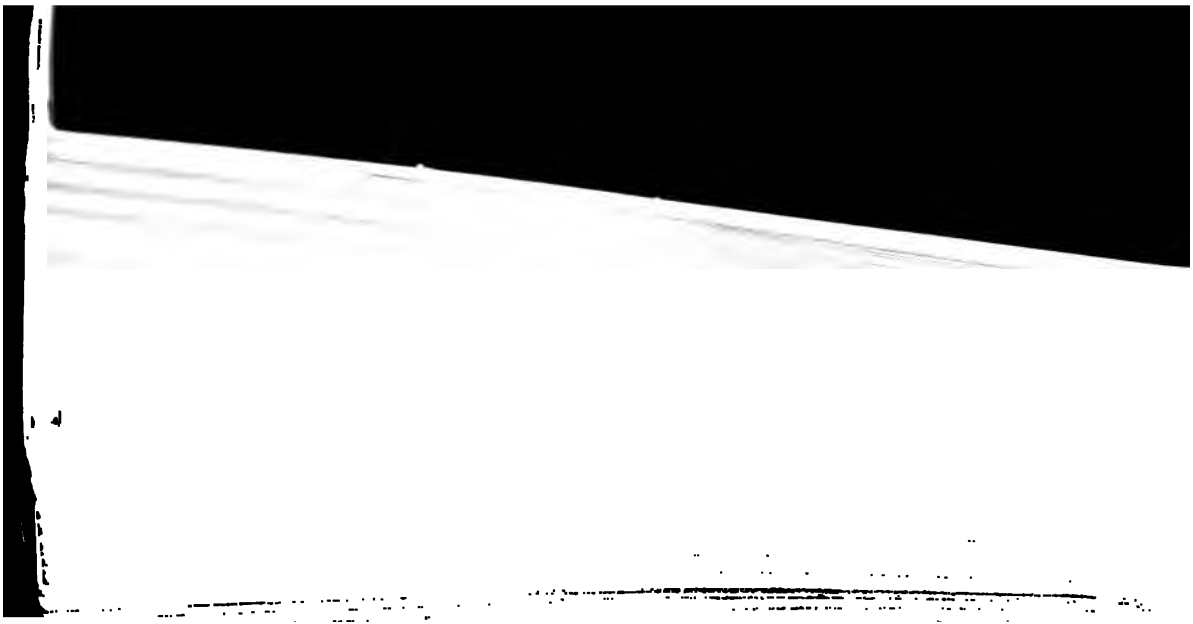
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